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# AN ANALYTIC PROCESS FOR THE EVALUATION OF STATE CORRECTIONAL PROGRAMS

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AN ANALYTIC PROCESS FOR THE EVALUATION

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# SUMMARY

The current emphasis on rehabilitation in correctional treatment dictates the need within correctional systems for a procedure to evaluate the rehabilitative efficacy of correctional programs.

The methodology developed in this thesis produces quantitative measures which can be used for comparative evaluation of the probable costs and results of alternative programs. These measures describe the probable effects of alternative programs on the average criminal career.

Using the Markovian assumption and sample data from the Georgia Department of Offender Rehabilitation, transition matrices descriptive of existing correctional programs are developed. Cost estimates are used to illustrate the development of the cost matrix and the application of economic discount techniques. A technique for using the methodology to develop estimates of system population is presented and discussed. The use of the methodology is illustrated through a series of examples involving hypothetical test cases. A computer program, written in BASIC language, is developed to assist in making the calculations involved.

Numerical results obtained throughout the thesis are illustrative in nature. The sensitivity of these results to data input indicates a need for refinement in some portions of the model. These areas and possible directions for refinement are presented and discussed.

# CHAPTER I

# INTRODUCTION

## Background

> At long last this nation is coming to realize that the process of justice cannot end with the slamming shut of prison gates.
>
> Ninety-eight out of every hundred criminals who are sent to prison come back out into society. That means that every American concerned with stopping crime must ask this question: Are we doing all we can to make certain that many more men and women who come out of prison will become law-abiding citizens?....
>
> President Richard M. Nixon, Message to National Corrections Conference, January, 1972 (39)

Throughout the last decade, correctional systems within the United States have been in a state of transition. This transition is the result of a recognition on the part of the public, government, and correctional administrators that the traditional theories of penology are no longer adequate. Experience of the past few years indicates that the percentage of those exposed to correctional programs who later return to crime is steadily increasing. This experience, together with increasing crime rates and the rising cost of maintaining correctional institutions, has motivated efforts to develop and implement correctional programs oriented toward the rehabilitation of social offenders.

Efforts by correctional administrators to implement a rehabilitative philosophy have been thwarted by tradition, political considerations, a lack of funds and other obstacles. Their ability to overcome these obstacles has been hampered by the lack of an effective procedure for evaluating the effectiveness of proposed correctional programs.

Almost all research to determine the results of correctional efforts has been done by social scientists. While this approach has been productive and noteworthy, it is the belief of this author that many of the problems connected with evaluating correctional programs can be solved more efficiently by applying some of the quantitative techniques employed by business and industry.

## System Overview

As indicated in Figure 1, corrections is a part of a larger, more complex system called the Criminal Justice System (CJS). The CJS, consisting of police, court and corrections subsystems, is responsible for controlling crime through the processes of arrest, adjudication, and correction. The society produces criminals who commit crimes, some of which are reported to the police. A portion of the reported crimes result in arrest of a suspect by the police. The suspect is brought before a court, where he is either convicted or found innocent and released back to society. If convicted by the court, the offender may be incarcerated or he may be released to society as the result of a suspended sentence, paying a fine, or placement on probation. Those who are incarcerated enter the corrections subsystem.

An individual may be thought of as existing in various states or conditions, as defined by his contact with the elements of society given in Figure 1. Thus a person not in contact with any part of the CJS is either in a free, law-abiding state or in a free, non-law-abiding state. As he moves downward in Figure 1

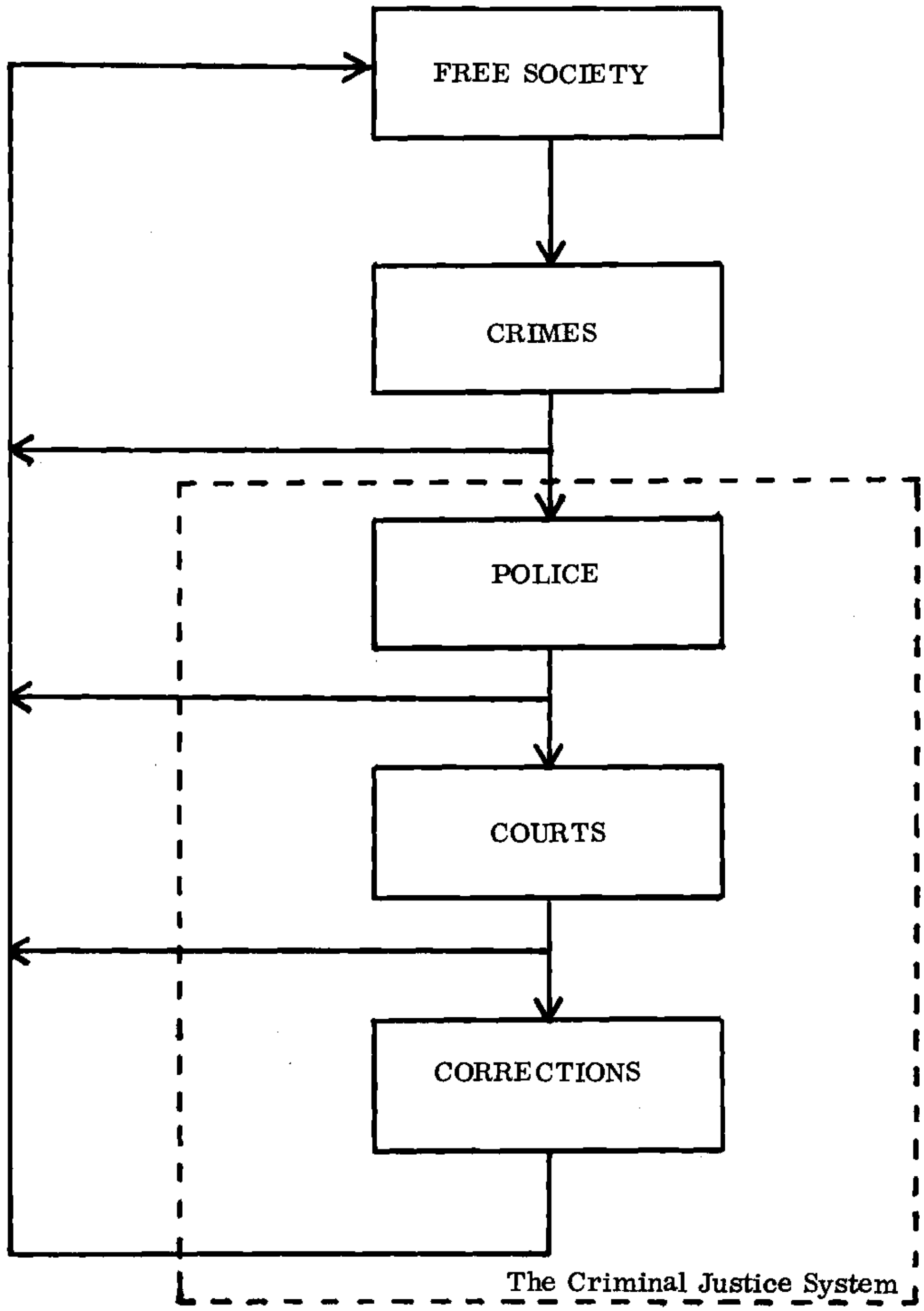


Figure 1. The Criminal Justice System.

from free society to the corrections subsystem, he may be thought of as passing through successive states: free law-abiding state; free non-law-abiding state; fugitive state or state of arrest; various states of adjudication, such as being free on bail, on trial, etc.; and the various states of correction shown in Figure 2.

Upon entering the corrections subsystem, the offender follows one of the paths shown in Figure 2. He is initially classified as to his security risk and his potential for rehabilitation. Following classification, the prisoner is assigned to a correctional institution, where he participates in one of the various correctional programs. Once committed to the corrections subsystem, an offender may serve a full sentence, after which he is released to society, or he may be granted parole. Of those granted parole, a percentage will be reincarcerated for technical violation of parole rules and a few will be reincarcerated as the result of conviction for a new crime committed while on parole. The remainder will successfully complete their parole and be discharged from the system. Of those discharged, some commit subsequent crimes for which they are returned to the system. These are called <u>recidivists</u>.

This research is concerned only with the corrections subsystem of the CJS. More specifically, the research is concerned with the analysis of the corrections subsystem within the state of Georgia. Throughout the remainder of the thesis, the term "corrections system" will be used to mean "state corrections subsystem."

Altering processes and programs within the corrections system will produce

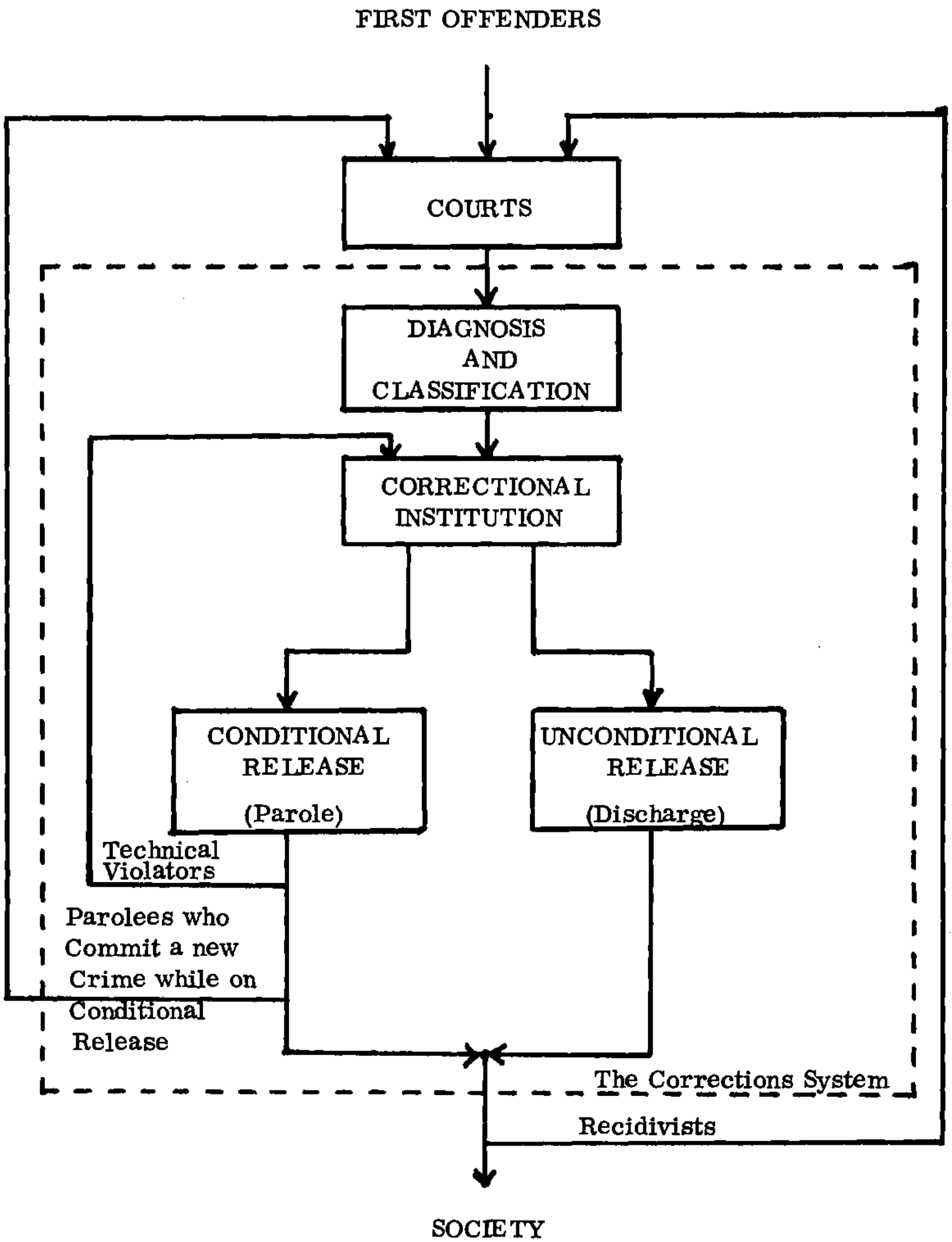


Figure 2. The Corrections System.

changes in both the number of persons who follow a particular path and in the costs associated with the various paths through the system. For example, a parole procedure that allows more inmates to be released on parole may reduce the institutional costs but may also result in an increase in parole violations and in the number of new crimes committed by parolees. Similarly, the implementation of a correctional program that assures that a greater percentage of those discharged are rehabilitated will decrease the number who return to the system as recidivists. However, the costs associated with such a program may be far greater than the costs associated with handling the recidivists. The methodology to be developed in this thesis will provide a means for systematically analyzing the expected costs and results associated with such changes in system processes and programs.

There are, of course, important interactions between the corrections system and other elements of the CJS. The efficiency of police operations and the sentencing policies of the courts have a direct effect on the input to the corrections system. Similarly, the effectiveness of the correctional effort affects the workload of the police and courts. In order to evaluate the corrections system by itself, certain assumptions must be made concerning these interactions. First, it is assumed that the number of first offenders arrested and convicted follows a predictable pattern. Secondly, it is assumed that the distribution of sentence lengths for those convicted remains constant. Finally, it is assumed that changes in correctional programs will not affect the efficiency of police or court operations. These assumptions, in effect, isolate the corrections system from the outside influences of the other elements of the CJS. Once the baseline model has been developed, the criticality of the assumptions can be checked through sensitivity analysis.

## Objective, Procedure and Scope

The primary objective of this research is to investigate the use of quantitative techniques in evaluating correctional alternatives. The investigation will consist of a survey of the appropriate literature, development of a model descriptive of the system currently in operation in Georgia, validation of the model, and illustrations of the use of the model for evaluating correctional alternatives.

The Markov assumption will be applied in developing the model. Using historical data as input for the model, specific measures associated with the current system will be generated as outputs. These measures will be:

1. The expected proportion of the current convicted population that will be in prison at any future date as the result of the current or future convictions.

2. The expected number of subsequent crimes for which the average member of the current convicted population will be reincarcerated.

3. The equivalent annual cost to society, per criminal career.

In addition, estimates of first offender input to the corrections system will be used in conjunction with the model to develop system population estimates for a ten year period.

The above measures will be produced for each of four categories of felons: assault, burglary, larceny, and robbery. Validation will consist of a comparison of the outputs of the model with the actual results being achieved by the existing system. Use of the model will be illustrated through the analysis of test cases representative of possible alternative programs.

To apply the methodology developed in this thesis, predictions of probable behavioral changes that may result from a prisoner's exposure to a particular penal program are needed. The literature surveyed (See Chapter II) indicates that adequate techniques are available for making such predictions. The scope of the thesis will be limited to developing a model that will use such predictions to produce quantitative measures of effectiveness for comparing alternative programs.

# CHAPTER II

# LITERATURE SURVEY

## Introduction

At various times in our national history, three broad goals have dominated correctional philosophy. In order of their emergence, they have been retribution, deterrence, and rehabilitation. Curiously, each is sometimes justified as a means to the other. Punishing offenders, and thus providing retribution or revenge for society, has been rationalized as a means of deterring and rehabilitating them. Deterrence by removal of the criminal from society has been seen both as a justifiable punishment and as a path to rehabilitation. More recently, advocates of rehabilitation have argued that reincorporating the individual into society may serve as the best possible deterrence against future crimes; yet they have also admitted that some punishment may be a useful means to rehabilitation. (11)

Roughly speaking, punishment and retribution were the main correctional themes in the 18th and 19th centuries; deterrence in the first half of the 20th century; and rehabilitation in the last two decades. Each of these themes can still be found coexisting in the laws and customs which control correctional activities today (4, 19, 35).

An exhaustive discussion of the available literature concerning each of these phases of correctional history is unnecessary. Only that material which has direct application to this thesis will be addressed. For ease in presentation, this material has been divided into the following categories:

1. Current correctional philosophy.
2. Methods of evaluating correctional efforts.
3. The cost of crime.
4. Analytic techniques applicable to the evaluation process.

## Current Correctional Philosophy

Over the last three decades sociologists, psychologists, and a few criminologists have been advocating a more rapid transition to the rehabilitation philosophy in correctional work. Their arguments have been widely published in various sociology and psychology journals. Perhaps the earliest and most influential of these advocates of current correctional philosophy was Thorsten Sellin, who has published and taught in the field of criminology since 1917. Throughout his work, he has ardently argued for more extensive testing of criminological theories. He was one of the first to argue the need for collecting useful criminal statistics to analyze and evaluate criminal justice procedures. A complete chronological bibliography of his work can be found in Crime and Culture: Essays in Honor of Thorsten Sellin (68).

Of equal importance is the work of Sheldon and Eleanor Glueck. These authors and scholars have produced a steady flow of books and articles on criminology since 1938. One of their most valuable contributions has been the investigation of the theory and practice of criminalistic prediction. In 1967, they published Ventures in Criminology (22), which summarizes their lifetime of work in the field. The book explains the background, methodology, and results of their numerous studies of criminals and criminal behavior. Their conclusions are that criminal careers can be altered through the proper administration of appropriate correctional programs and that subsequent criminal behavior can be successfully predicted from the results of psychological testing and observation. More recent studies by Wolfgang (69), Einhorn (14), and Halpin (26) support these conclusions.

In 1965, John Conrad characterized the correctional apparatus within the United States as "still oscillating among the three objectives of retribution, deterrence, and rehabilitation" (9). He concludes that the transition to the rehabilitation philosophy is being hampered by four basic conflicts within the correctional system. These conflicts are:

1. The conflict of control and change--the role of the prison staff is to control through force, while implementation of proposed changes requires permissiveness and individualization.
2. The conflict of objectives and capabilities--the official goals of corrections are clear. However, the capabilities to achieve these goals are restricted, in Conrad's opinion, by ignorance.
3. The conflict of standard and actual practice--concern and care for criminals is difficult to engender and sustain. It is easier to construct and justify systems that will punish the offender and protect the public than to provide for change and create systems that facilitate change.
4. Conflict of tradition and reason--more effective measures may be conceived, but Conrad feels that confidence in reason will be superseded by the weight

of tradition until reason is overwhelmingly reinforced by experimental evidence. Although more recent literature indicates that the transition has progressed, there is evidence that these conflicts remain imbedded in correctional systems today.

Despite the quantity and quality of earlier work concerning current correctional philosophy, it was not until the President's Commission on Law Enforcement and the Administration of Justice published its report and recommendations in 1967 that these theories gained widespread acceptance and limited implementation was begun (58). The Commission was established on July 23, 1965, by President Johnson. He instructed it to inquire into the causes of crime and delinquency and report to him with recommendations for preventing crime and delinquency and improving law enforcement and the administration of criminal justice.

The work of the Commission was initially divided into four major areas: police, courts, corrections, and assessment of the crime problem. Concentrating on each was a task force consisting of a panel of Commission members, a number of full-time staff members, and consultants and advisers. The Commission's research and inquiries took many forms. Surveys were conducted in connection with work on police-community relations, professional criminals, unreported crime, and correctional personnel and facilities. The corrections survey, sponsored jointly by the Commission and the Office of Law Enforcement Assistance, was the first nationwide study ever made in this area. Commission staff and representatives visited correctional institutions, met with groups of residents in slum areas, and interviewed professional criminals and prison inmates.

Based on their relatively extensive investigation of the correctional problem, the Commission concluded that for many offenders, corrections do not correct. Rather, the conditions under which many offenders are handled, particularly in institutions, are often a positive detriment to rehabilitation (58, p. 159). Based on their research, the Commission developed several recommendations for improving rehabilitative efforts. These recommendations emphasized the need for community-based corrections, increased use of and more efficient administration of probation and parole systems, improved training and increased education of correctional personnel, and more emphasis on individualization of treatment during incarceration and rehabilitation.

Following the publication of the Commission's report, criminology experts and practitioners began to reexamine these theories and to search for means of implementing the Commission's recommendations. According to the Library of Congress, over 500 books, articles, and monographs on the subject of corrections were published during the two and one-half year period following release of this report (60).

The work by Dinitz (12), Gibbons (19), and Johnson (35) in 1968 and by Barnes (4) and Schafer (51) in 1969 tended to support the conclusions drawn by the Commission and reemphasized the need for immediate and thorough correctional reform. At the same time, Blumstein (5) and Bower (7) began to investigate the application of analytic techniques, specifically the techniques of Operations Research and Systems Analysis, to the criminal justice system.

In 1970, the President's Task Force on Prisoner Rehabilitation published its report (60). Concerned primarily with investigating the status of rehabilitative efforts in correctional systems throughout the United States, their report reiterated the need for improving the ways in which institutions go about helping criminals to become law-abiding citizens. They pointed out that these improvements would cost large amounts of money and that, therefore, some systematic process for determining the most effective programs must be developed in order to preclude wasting funds on nonproductive efforts.

An investigation by Congressman Lee H. Hamilton (27) approximately one year later indicated that there had been little improvement with respect to rehabilitation. Citing FBI statistics to support the claim that the heart of the overall crime problem lies in repeated offenders, he stated that "our number one objective in the war on crime should be the rehabilitation of the people now under correctional control. Every dollar spent on rehabilitating a convicted person has the potential for being more cost-effective than a dollar spent in any other area of national endeavor."

Thus it appears that although current correctional philosophy dictates total commitment to rehabilitation, current correctional practice falls considerably short of this total commitment. This gap exists, according to Howlett and Hurst (34), because "planning for criminal justice continues to be based upon subjective hunches, untested assumptions, and political whims." The gap will continue to exist as long as there is no scientific program for evaluating correctional and rehabilitative programs. The explicit need for such a program has been a central theme throughout the literature.

## Evaluation Methods

Given the inadequacy of programs for evaluation indicated by the literature, it is appropriate at this point to examine the literature concerning evaluation techniques and to analyze the evaluation programs which have been proposed or implemented.

In most of the literature addressing the evaluation problem, the measures by which the effectiveness of correctional programs have been tested have been crime and recidivism rates. Over the past decade, however, there has been increased concern over the limitations of these measures. Conrad summarized this concern in 1965, and proposed some directions for improving evaluation techniques (9). The problem, Conrad stated, is that messages conveyed by tables of crime and recidivism may be misleading. The efficacy of correctional service is only one among many forces impinging upon the offender after his release. It may play no part in his success, it may play a limited part, or it may have a crucial influence. Conrad concluded that there was a necessity to establish expectations for different kinds of offender through the use of base expectancies and prediction tables. Only through the application of scientific method to correctional data, he stated, could conclusive comparisons be made.

Concerned with the inadequacies of the simple crime rate as a measure of effectiveness, Sellin and Wolfgang (53) developed the Sellin-Wolfgang Index for comparing alternative programs. This Index measures the seriousness as well as the incidence of crime; it therefore is a more sophisticated tool than the simple crime rate. Used to compare the crime committed by a group of offenders released after one program to that committed by a group released after another program, the Index can show if one rate is lower as well as whether the new program has at least produced a shift to crime of lesser severity. One problem associated with using the Sellin-Wolfgang Index as a corrections effectiveness measure is that it does not contain values for incidents that are parole violations and not really crimes. This problem can be overcome by assigning an arbitrary but low value to technical violations. When this is done, however, the cumulative Index scores reflect the parole authorities attitudes as well as crime events.

Although simple recidivism rates are generally accepted as usable and easily understood measures of effectiveness, the National Commission on the Causes and Prevention of Violence (11) concluded that such rates must be used with caution. The main problem with this measure is that the mobility of offenders makes it difficult to ascertain an accurate recidivism rate. No nationwide data collection agency exists that can trace a person who flees to another state and commits a crime. Had such a crime been committed in the original jurisdiction, it would have been associated with that prisoner's release and included in the official recidivism rate. Reported recidivism rates tend to be lower than the actual rates because individuals not known to be in custody of other jurisdictions are often counted as successful rehabilitants.

In addressing this same problem, Wilkins (65) concluded that the lack of a universal definition of recidivism creates additional doubts about the validity of using these rates as measures of effectiveness. He points out that, in some jurisdictions, only those who are returned to prison are classified as recidivists, while other jurisdictions regard the commission of any further offense as warranting this classification.

Mahoney and Blozen (44) proposed some additional measures of correctional effectiveness. With respect to parole programs, for example, they produced a measure called "percent in prison." If, for any group of parolees, the amount of time they are likely to spend in the system can be determined, the number of parolees from the cohort who are likely to be in the system at any point in time can also be determined. This figure, calculated for successive units of time, following release on parole for a given cohort, is a real measure of the parole project's effectiveness.

Another measure which they proposed is that of "prison months." This measures the amount of time that returnees are likely to spend in a reformatory, prison, or other custodial institution. The amount of time is a function of a number of things, such as the offense that resulted in incarceration, prior criminal history, and behavior during the period of incarceration. To calculate the measure, returnees are matched with expected time to be served by the reason for return.

Two other measures which are discussed by these authors are prediction of the average time out of prison of an individual once he has been released and prediction of the expected average time in prison once an individual has entered. These measures are based on a statistical prediction model using Markov Chain Theory. These last two concepts were used by Blumstein (6) in developing his model of a total criminal justice system.

In discussing evaluation of correctional programs, the National Commission on the Causes and Prevention of Violence concluded that the measures required will vary according to the specific needs of individual projects. No single measure can embrace all the objectives of a program. A simple recidivism rate, for example, does not consider the severity of the crime committed, tells nothing of the performance of those not returned to prison, and does not always account for the order of the return to prison (i.e., whether it is the first, second, third, etc., incarceration). Other measures might provide insight into the areas not covered by a simple recidivism rate, but they also fall short of telling the entire story. Thus, they conclude, just as a set of economic indicators has come to be used in appraising the economy, so a set of measures appears necessary for testing and evaluating corrections programs (11, p. 578). More recent evaluation studies conducted by Glaser (20), Johnston, et al. (36), and Wilkins (65) support these conclusions.

Gottfredson (23) discusses two general approaches to correctional program evaluation. These two approaches are the analysis of experiments designed to test hypothesis and the analysis of experience through systematic study of natural variation among programs and their outcomes. The first of these requires an experiment design which will minimize bias and the effect of indiscriminate manipulation and which will provide the required information. It also involves the use of human beings for experimental purposes, a factor which has not received universal acceptance among some political and social groups. The second approach uses statistical methods to draw inferences and make predictions from the analysis of historical data. In Gottfredson's opinion, the ideal evaluation process must contain some appropriate mix of these two approaches.

After reviewing studies of corrections in California, Robison and Smith (48) concluded that available correctional alternatives had little or no impact on the likelihood of recidivism among offenders. Their studies considered five critical choices in offender processing: (1) imprisonment or probation, (2) length of stay in prison, (3) treatment program in prison, (4) intensity of parole or probation supervision, and (5) outright discharge from prison or release on parole. They concluded that variations in recidivism rates among these alternatives were attributable to initial differences among the types of offenders or to difference in interpreting an event as a violation. They found no evidence to support claims of superior rehabilitative efficacy of one correctional alternative over another.

In addition to the literature which is directed specifically to the problem of evaluating correctional programs, there is considerable literature dealing with evaluation of social programs in general which should also be considered in developing an evaluation process for corrections. Although most of this work has been oriented toward welfare and mental health programs, the theories and principles involved are equally applicable to correctional programs. Discussions of these theories and principles can be found in the following references: Banks (3), Levine (40), Levinson (41), Stein, et al. (54), Suchman (56), Williams (66), and Wholey, et al. (67).

The concept of measured effectiveness basic to the evaluation process developed in this thesis comes from the literature on economic "cost-effectiveness" analysis. The purpose of such analysis is to compare the cost and effectiveness of alternative means to achieve the desired ends of a program. This comparison is made by deriving from the ends of a stated program certain criteria by which the success of alternative approaches can be assessed, and by then combining these assessments with cost estimates. With respect to the correctional system, this requires the determination of costs associated with incarceration and rehabilitation and the costs of crimes committed. Costs associated with incarceration and rehabilitation, although relatively involved, are not extremely difficult to ascertain. Accurate assessment of the costs of crimes, however, presents a much more difficult and complex problem.

## The Cost of Crime

Many scholars have attempted to measure the economic costs of crime in the United States. The first comprehensive study of this problem was undertaken by the so-called Wickersham Commission (46) in 1931. It set forth in detail a conceptual framework for discussing the economic cost of crime and recommended that further studies be made. Except in the area of statistics concerning the cost of the criminal justice system, their recommendations went unheeded until 1967, when the President's Commission on Law Enforcement and the Administration of Justice (10) investigated the problem.

By its own admission, the President's Commission's study of the costs of crime was incomplete. In its discussion, the Commission divided economic costs into those associated with criminal acts and those required to maintain a system of law enforcement, criminal justice, and crime prevention. The costs of criminal acts were further divided into crimes against property, crimes against the person, other crimes, and illegal goods and services. The concept of costs to society was defined by the Commission in terms of total dollar volume of crime. In calculating their estimates, the Commission considered foregone earnings based on earning potential, medical expenses, lost production, and the cash value of goods and property taken, damaged, or destroyed.

In 1968, Wolfgang (70) addressed this same problem. His approach was similar to that of the President's Commission and he offered cost estimates for many of the same areas of criminal activity. Wolfgang's estimates for each category differed considerably from those of the President's Commission because a different data source was used and because of different techniques used in calculating the actual estimates. For a detailed category by category comparison of these two studies, see Crime of Violence (11, pp. 400-405).

Later that same year, Mahoney and Blozan (44) offered a study of the underlying economic issues involved in estimating the costs of crime. Although they developed no comparative cost estimates, these authors discussed in detail the costs and benefits associated with criminal rehabilitation and stressed the contribution of rehabilitation programs to the increased return on human capital.

The issues of determining the costs of crime and the implications of these costs were taken up at the Second International Symposium in Comparative Criminology in 1970. For estimation purposes, the participants agreed, social costs related to criminal offenses should be divided into three categories: 1) the alternative or opportunity costs of scarce resources employed by criminals; 2) the cost of destroyed goods or assets whose replacement value represents a reduction of national wealth; and 3) the value of costs of economic resources foregone for public and private protection against criminal activities. Although these are all pecuniary as opposed to intangible costs, no conclusion was reached as to what value should be attached to each category (59).

In 1971, Zimring (72) reemphasized the need for accurate cost data for establishing priorities in choosing among correctional alternatives. He stated that the study of costs in crime prevention is necessary for policy research purposes as well as accounting purposes. These studies must seek to establish the types and amount of program costs and the cost and relative effectiveness of alternative methods of achieving the same objectives. He did not, however, offer any suggestions as to how these costs might be obtained.

From the above discussion of the literature, it is clear that the problem of establishing a valid estimate of the costs of crime is very complex indeed. But, as the National Commission on Crime and Violence concluded, this does not mean that attempts at such estimates are not useful. On the contrary, such attempts are vital if correctional programs are to be properly evaluated.

## Markov Processes

As stated in Chapter I, a Markov model of a typical criminal career will be a key element of the evaluation process. Tullier (62) and Watts (64) have demonstrated that the Markov technique can be used to model corrections systems. Tullier used the technique to analyze the effects of various parole procedures in California, while Watts developed a Markov model of the criminal population. In both cases, the scope of the research was limited to only one aspect of the corrections problem. Their results, however, provide conclusive evidence that the Markov technique is an appropriate tool for the analysis of correctional programs. The remainder of this section is devoted to a review of the basic concepts of Markov chains as they apply to this research.

Consideration of the behavior of a system operating for some period of time often leads to the analysis of a stochastic process with the following structure. At particular points of time t ($t = 0, 1, 2, \ldots$), the system is found in exactly one of a finite number of mutually exclusive and exhaustive categories, or states, labelled $0, 1, \ldots, M$. Although these states may constitute a qualitative as well as quantitative description of the system, no loss of generality is entailed by the numerical labels used to denote the possible states of the system (31). Many systems have the property that given the present state, the past states have no influence on the future. This property is called the Markov property, and systems having this property are called Markov chains. More specifically, a finite-state Markov chain is defined as a stochastic process which has the following:

1. a finite number of states,
2. the Markovian property,
3. stationary transition probabilities,
4. a set of initial probabilities, $P(X_o = i)$ for all i (31, p. 404).

The Markov property is defined precisely by the requirement that $P(X_{t+1} = j \mid X_o = k_o, X_1 = k_1, \ldots, X_{t-1} = k_{t-1}, X_t = i) = P(X_{t+1} = j \mid X_t = i)$ for $t = 0, 1, 2, \ldots$, and every sequence, $i, j, k_o k_1, \ldots, k_{t-1}$ (31). The conditional probabilities, $P(X_{t+1} = j \mid X_t = i)$, are called transition probabilities. If, for each i and j, $P(X_{t+1} = j \mid$

$X_t = i) = P(X_1 = j | X_o = i)$, for all $t = 0, 1, 2, \ldots$, then the one-step transition probabilities are said to be stationary and are usually denoted by $p_{ij}$. The existence of stationary one-step transition probabilities implies that the probabilities do not change with time, that is, for each i, j, and n (n = 1, 2, 3, ...)

$$P(X_{t+n} = j | X_t = i) = P(X_n = j | X_o = i), \text{ for } t = 0, 1, 2, \ldots.$$

These conditional probabilities are usually denoted by $p_{ij}^{(n)}$ and are called n-step transition probabilities. $p_{ij}^{(n)}$ is simply the conditional probability that the random variable X, starting in state i, will be in state j after exactly n time units. Since these values are probabilities, they must satisfy the requirements

$$p_{ij}^{(n)} \geq 0 \text{ for all } i \text{ and } j, \text{ and } n = 1, 2, \ldots$$

and

$$\sum_{j=o}^{M} p_{ij}^{(n)} = 1, \text{ for all } i \text{ and } n = 1, 2, \ldots$$

A convenient notation for representing the transition probabilities is the matrix form,

$$p^{(n)} = \begin{bmatrix} p_{oo}^{(n)} & \cdots\cdots & p_{om}^{(n)} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ p_{mo}^{(n)} & \cdots\cdots & p_{mm}^{(n)} \end{bmatrix}, \text{ for } n = 1, 2, \ldots$$

This n-step transition matrix can be obtained by computing the $n^{th}$ power of the one-step transition matrix (31, p. 403-406).

The n-step transition probability matrix can also be used to find the expected number of times that a particular state will be visited during a given time period. If the process starts in state i, the expected number of times the process will be found in state j during times m = 1, 2, . . . , n is given by

$$E_i(N_n(j)) = \sum_{M=1}^{N} p^m(i,j) \qquad (33,\ p.\ 57)$$

If a cost, C(j), is incurred when the process is in a state j at time t, for t = 0, 1, 2, . . . , then the long-run expected average cost per unit time can be computed from the relation

$$E(C) = \sum_{j=0}^{M} C(j)\ \pi_j .$$

where the $\pi_j$'s are the steady-state probabilities (31, p. 416). The term "steady-state" probability means that the probability of finding the process in a particular state after a large number of transitions approaches the value $\pi_j$, independent of the initial probability distribution defined over the states. It is important to note that "steady-state" probability does not imply that the process settles down into one state. On the contrary, the process continues to make transitions from state to state, and, at any step n, the transition probability from state i to state j is still $p_{ij}$. In more precise terms,

$$\pi_j = \lim_{n \to \infty} p_{ij}^{(n)} .$$

where the $\pi_j$'s uniquely satisfy the following equations:

$$\pi_j > 0,$$

$$\pi_j = \sum_{i=o}^{M} \pi_i p_{ij}, \text{ for } j = 0, 1, \ldots, M,$$

$$\sum_{j=0}^{M} \pi_j = 1 \qquad (31, \text{ p. } 413)$$

In other words, the vector $\pi$ is the unique probability vector such that $\pi p = \pi$ (37, p. 71).

Since there is a possibility that a Markov process will make repeated, consecutive transitions back to the same state, the analyst is frequently interested in determining the number of times in succession that the same state is occupied after it is first entered. This statistic is generally called the holding time of the state and is denoted by $t_i$. It can be shown that the mean holding time for a particular state $i$ is given by

$$t_i = \frac{1}{1 - p_{ii}} \qquad (73, \text{ p. } 241)$$

Another parameter which is generally of interest in Markov chains is the expected amount of time (expected number of transitions) it takes the process to reach state j for the first time if the system is in state i at time zero. This parameter is called the expected first passage time and is usually denoted by the symbol $\theta_{ij}$. For a finite state Markov chain, $\theta_{ij}$ satisfies uniquely the equation

$$\theta_{ij} = t_i + \sum_{k \neq j} p_{ik}\ \theta_{kj} \qquad (73, \text{ p. } 642)$$

Expanding this equation for all $i$ will produce a system of i equations with i unknowns that can be solved simultaneously for the unique solution $\theta_{ij}$.

In addition to the previously cited references, detailed discussions of Markov theory can be found in Halperin (25), Hitchcock (32), Magazine (42), and Ross (49).

## BASIC Programming Language

For systems in which the number of states is small and only a few steps are to be considered, the calculations involved in analysis of Markov chains can be handled manually. However, for large transition matrices and when a large number of steps must be considered, manual calculations become tedious and time consuming and increase the potential for error. Such problems can, however, be solved quickly and accurately with the aid of a computer.

Several available programming languages could be used to make the calculations involved in this research. Of these, BASIC appears to be most appropriate. BASIC (Beginner's All-purpose Symbolic Instruction Code) is a simple algebraic language that has been implemented on a wide range of hardware systems. It is user-oriented and may be learned in just a few hours of concentrated study. The language, which resembles FORTRAN, makes use of standard mathematical notation familiar to most scientifically trained people. BASIC contains a powerful arithmetical facility, many language diagnostics, several editing features, a library of matrix functions, and simple input and output procedures (55). BASIC, as available for use in a time-shared mode on the UNIVAC 1108 at Georgia Tech, was used in the calculations for this thesis.

# CHAPTER III

# DEVELOPMENT OF THE METHODOLOGY

## The Markovian Assumption

As stated in Chapter I, the Markovian assumption will be used in developing a model of the Georgia Corrections System. In general, the assumption says that the probability of moving from one state in the system to any other state depends only on the state presently occupied. There are few real systems that could be expected to be so memoryless in a strict sense. Yet, if the Markovian assumption can be justified, then the investigator can enjoy analytical and computational convenience not often found in more complex models. Based on the work of Tullier (62) and Watts (64), the assumption appears warranted.

## Definition of States

As indicated in the discussion of Figure 1 (Chapter I, p. 3), persons passing through the Criminal Justice System may be thought of as being in one of a number of states or conditions. The possible states of the Markov model can be defined in terms of these various conditions. With respect to the corrections system, two very general states are immediately evident--in prison and out of prison. This general categorization does not, however, provide correctional administrators with sufficient information to determine the effectiveness of correctional alternatives. Thorough analysis requires more detailed knowledge about the composition of each of these categories. This requirement can be satisfied by decomposing the general categories and defining additional states.

Recalling from Figure 2 (Chapter I, p. 5) that there are two ways in which criminals enter the corrections system, by conviction or by technical violation, the "in prison" state can be decomposed according to mode of entry. Similarly, those who enter the "out of prison" state can be classified according to the type of release, paroled or discharged. Using this procedure, the two general states can be expanded into the four states defined below:

State 1--In prison because of conviction. This state includes those who are convicted for subsequent crimes while on supervised release programs or after being released without supervision. This state will be called IN(C).

State 2--On parole. This state includes all supervised release programs. It will be designated by OUT(P).

State 3--In prison because of technical violation of supervised release conditions (no new crime involved). This state will be designated IN(TV).

State 4--Free. This state includes all who are released without supervision, e.g., completed sentence, completed parole, pardon, etc., and will be called OUT(D).

Further decomposition could be carried out, resulting in an increase in the number of possible states. For example, the four states defined above could be broken down by age classification, or by the number of returns to the system, or by both. Increasing the number of states, however, results in a substantial increase in the amount of data that must be collected or estimated and compounds the complexity of the calculations involved. It is therefore desirable to limit the number of states as much as possible, while insuring that the desired outputs are produced and that the dynamic characteristics of the system are adequately represented. A Markov model of the corrections system, consisting of the four states defined, will satisfy this requirement while retaining the distinct advantage of being easily understood and manipulated.

Using these states, the Markov model can be represented schematically, as in Figure 3, where the entries in the matrix represent the probabilities of moving from state i to state j in one step. The step size for the model is one year. For the purpose of this research, the initial state is assumed to be IN(C), in prison because of conviction.

$$\begin{array}{cc}
 & \begin{array}{cccc} \text{State 1} & \text{State 2} & \text{State 3} & \text{State 4} \\ \text{IN(C)} & \text{OUT(P)} & \text{IN(TV)} & \text{OUT(D)} \end{array} \\
\begin{array}{l} \text{State 1--IN(C)} \\ \text{State 2--OUT(P)} \\ \text{State 3--IN(TV)} \\ \text{State 4--OUT(D)} \end{array} & \begin{bmatrix} X & X & & X \\ X & X & X & X \\ & X & X & X \\ X & & & X \end{bmatrix}
\end{array}$$

Figure 3. Schematic Markov Model

## The Transition Matrices

As indicated by the literature discussed in Chapter II, a key element of the Markov process is the one-step transition matrix. The individual elements of this matrix are the conditional probabilities that the process will move from one state to another in exactly one time unit. Within the corrections system, these probabilities are affected by a number of factors, such as length of sentence and parole eligibility regulations. Because of the variations caused by these factors, it is not possible to accurately represent the entire criminal population with a single transition matrix. One can, however, develop a transition matrix that is representative of that portion of the population which has been convicted for a particular type of crime. With such transition matrices, the Markov model can be used to develop predictions about the probable criminal careers of those incarcerated for any of the various crime types.

The criteria for selecting the crime categories to be analyzed is usually determined by the purpose of the investigation and the availability of data. To illustrate the baseline model, transition matrices for each of four categories of felons have been developed. To facilitate comparison of data for the Georgia system to national data, the categories selected correspond to four of the so called index crimes. (Index crimes are the types of crime tabulated annually by the Federal Bureau of Investigation to arrive at a national crime index.) The categories selected are assault, robbery, burglary, and larceny. The category of assault includes the following crimes: aggravated assault, assault with intent to murder, assault with intent to rape, and manslaughter. The category of larceny includes simple larceny of $50 or more, larceny of household, and larceny of motor vehicles.

The transition matrices for each of these categories are shown in Figures 4 through 7. These matrices are based on data for the Georgia Corrections System

| | State 1 IN(C) | State 2 OUT(P) | State 3 IN(TV) | State 4 OUT(D) |
|---|---|---|---|---|
| State 1--IN(C) | .514 | .288 | 0 | .198 |
| State 2--OUT(P) | .085 | .248 | .123 | .544 |
| State 3--IN(TV) | 0 | .127 | .630 | .243 |
| State 4--OUT(D) | .130 | 0 | 0 | .870 |

Figure 4. Transition Matrix--Initial Crime of Assault.

| | State 1 IN(C) | State 2 OUT(P) | State 3 IN(TV) | State 4 OUT(D) |
|---|---|---|---|---|
| State 1--IN(C) | .609 | .192 | 0 | .199 |
| State 2--OUT(P) | .059 | .305 | .087 | .549 |
| State 3--IN(TV) | 0 | .096 | .689 | .215 |
| State 4--OUT(D) | .090 | 0 | 0 | .910 |

Figure 5. Transition Matrix--Initial Crime of Robbery.

| | State 1 IN(C) | State 2 OUT(P) | State 3 IN(TV) | State 4 OUT(D) |
|---|---|---|---|---|
| State 1--IN(C) | .502 | .242 | 0 | .256 |
| State 2--OUT(P) | .062 | .325 | .093 | .520 |
| State 3--IN(TV) | 0 | .116 | .626 | .258 |
| State 4--OUT(D) | .220 | 0 | 0 | .780 |

Figure 6. Transition Matrix--Initial Crime of Burglary.

$$\begin{array}{l} \\ \\ \text{State 1--IN(C)} \\ \text{State 2--OUT(P)} \\ \text{State 3--IN(TV)} \\ \text{State 4--OUT(D)} \end{array} \begin{array}{c} \begin{array}{cccc} \text{State 1} & \text{State 2} & \text{State 3} & \text{State 4} \\ \text{IN(C)} & \text{OUT(P)} & \text{IN(TV)} & \text{OUT(D)} \end{array} \\ \begin{bmatrix} .590 & .198 & 0 & .212 \\ .054 & .356 & .078 & .512 \\ 0 & .096 & .655 & .249 \\ .160 & 0 & 0 & .840 \end{bmatrix} \end{array}$$

Figure 7. Transition Matrix--Initial Crime of Larceny.

for the years 1967-1971. Raw data and computations are in Appendix I.

## The Cost Matrix

The cost portion of the model must include procedures that account for the costs associated with commission of a crime, arrest and conviction for that crime, and implementation of the sentence imposed. It is convenient to interpret these costs in terms corresponding to the states defined for the Markov model, that is: the cost of the crime itself and the cost of arrest and conviction are equivalent to the cost of making a transition from parole status (OUT(P)) or free status (OUT(D)) to convicted status (IN(C)); the costs associated with implementing the imposed sentence are equivalent to the cost of remaining in any state for one step plus the costs of transitions among states OUT(P), IN(TV), and OUT(D). Schematically, all of the cost factors can be represented by constructing a cost matrix similar to that in Figure 8.

$$
\begin{array}{l}
 \\ \text{IN(C)} \\ \text{OUT(P)} \\ \text{IN(TV)} \\ \text{OUT(D)}
\end{array}
\begin{array}{c}
\begin{array}{cccc} \text{IN(C)} & \text{OUT(P)} & \text{IN(TV)} & \text{OUT(D)} \end{array} \\
\begin{bmatrix}
C_{11} & C_{12} & C_{13} & C_{14} \\
C_{21} & C_{22} & C_{23} & C_{24} \\
C_{31} & C_{32} & C_{33} & C_{34} \\
C_{41} & C_{42} & C_{43} & C_{44}
\end{bmatrix}
\end{array}
$$

Figure 8. Conceptual Cost Matrix

$$
\begin{array}{l}
 \\ \text{IN(C)} \\ \text{OUT(P)} \\ \text{IN(TV)} \\ \text{OUT(D)}
\end{array}
\begin{array}{c}
\begin{array}{cccc} \text{IN(C)} & \text{OUT(P)} & \text{IN(TV)} & \text{OUT(D)} \end{array} \\
\begin{bmatrix}
2890.80 & 1856.12 & 0 & 1270.40 \\
6226.12 & 621.44 & 1906.12 & 60.72 \\
0 & 1856.12 & 2890.80 & 1270.40 \\
5647.40 & 0 & 0 & -550.00
\end{bmatrix}
\end{array}
$$

Figure 9. The Cost Matrix

Figure 9 shows the cost matrix used to illustrate development of the methodology. The cost data and computational procedures used to determine the individual elements of this matrix are contained in Appendix II. It should be emphasized that the data in Appendix II represents the best estimate of costs which could be obtained in the time allotted for this research. Because of time and data limitations, neither welfare costs directly attributable to criminal activity nor the contribution to the economy of gainfully employed parolees was included in the cost computations. Should further research be conducted in this area, the cost data should be refined to a more acceptable level of accuracy and should include those factors not included in this research.

The diagonal elements of this matrix ($C_{11}$, $C_{22}$, $C_{33}$, $C_{44}$) represent the cost of making a transition from state i back to state i in one step. Equivalently, this is the cost of remaining in a particular state for one year. Thus, $C_{11}$ and $C_{33}$ are equal and represent the cost of remaining in prison for one year. Similarly, $C_{22}$ is the cost of being on parole for one year and $C_{44}$ is the yearly contribution of a discharged prisoner to the state economy (represented as a negative cost).

The remaining elements of the matrix are the costs associated with moving from state i to state j in one year, e.g., prison to parole, parole to free, etc. Since it is not possible to go from convicted status (IN(C)) directly to technical violator status (IN(TV)), the cost element associated with this transition ($C_{13}$) is meaningless and can be defined as zero. Similarly, the elements $C_{31}$, $C_{42}$, and $C_{43}$ are all zero since transitions associated with these elements are not possible.

Because the model does not specify the portion of a year that the process spends in state i before going to state j, it is necessary to assume that the process spends one-half year in each state. The remaining $C_{ij}$'s can then be computed as

$$C_{ij} = 1/2\,C_{ii} + 1/2C_{jj} + K_{ij}$$

where $K_{ij}$ is the cost associated with effecting the transition (e.g., cost of parole proceedings, cost of discharge, etc.).

The costs associated with keeping an individual in prison for a year vary depending upon the crime for which the person is incarcerated. These variations result from different security requirements, participation in differing rehabilitation programs, and other factors. Current cost accounting procedures within the Georgia system do not identify prison costs by crime category. The values used in the cost matrix are, therefore, averages taken over all crime categories.

## Computational Procedures

Once the transition matrices and the cost matrix have been developed, Markov chain theory as discussed in Chapter II can be applied to produce the desired outputs. These outputs are the measures that will be used to evaluate correctional alternatives. As specified by the Georgia Department of Offender Rehabilitation, these measures are:

1. The expected proportion of the current prison population that will be in prison at any future date.

2. The expected number of subsequent crimes for which the average member of the current prison population will be reincarcerated.

3. The equivalent annual cost to society, per criminal career.

Determination of the first measure is equivalent to finding the probability that the process will be in state 1 after N years, given that it started in state 1. This is simply the element (1, 1) of the transition matrix to the nth power, $n = 1, 2, \ldots, N$ years.

To compute the second measure, it is necessary to find the expected number of nonconsecutive returns to state 1 during the number of steps considered. This can be accomplished through the use of a "payoff" matrix and the value-determination operation presented by Howard (74, pp. 34-36). Assume that there is a payoff associated with the process being in state 1. Let this payoff be one if the process is in the state, and zero otherwise. The payoff matrix, R, can then be written as

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \\ r_{41} & r_{42} & r_{43} & r_{44} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

Now define $G_n$ as the average payoff per transition and $v_i$ as the immediate relative value of a transition to state i. Using Howard's value-determination operation, the quantity G can be found from the set of linear equations

$$G = \sum_{j=1}^{4} p_{ij} r_{ij} + \sum_{j=1}^{4} p_{ij} v_j - v_i, \qquad i = 1, 2, 3, 4.$$

Expansion of this relation will give a system of four equations with five unknown values. Since the parameter of interest is G, assume that one of the $v_i$ is zero. This is permissible since the $v_i$ are relative values and have no real significance in processes that continue for a large number of transitions (74, p. 35). The system of equations can then be solved simultaneously for G. This number can then be multiplied by the number of transitions considered to find the expected number of nonconsecutive returns to prison by conviction.

The equivalent annual cost to society per criminal career is found by using the cost matrix in conjunction with the transition matrices and simple economic discount techniques. Denote the average annual cost per criminal for year n by $Y_n$. Let $W(J)_n$ be a row vector equal to the first row of the transition matrix to the nth power. Then the elements of $W(j)_n$ represent the proportion of the current convicted population that will be in each of the states at the end of year n. The average cost per criminal, $Y_n$, is the sum over all states of the cost of visiting a state multiplied by the proportion of criminals in the state. That is

$$Y_n = \sum_j \left[ \left( \sum_i p_{ij} C_{ij} \right) W(j)_n \right]$$

The present worth of these yearly costs is found from the relation

$$P = \sum_{n=1}^{N} y_n \left( \frac{1}{1+i} \right)^n$$

where i is the effective annual interest rate for continuous compounding. The equivalent annual cost, A, is related to the present worth by

$$A = P\left[ \frac{e^r - 1}{1-e^{-rn}} \right]$$

where r is the nominal interest rate (61, p. 74). The nominal interest rate is related to the effective interest rate by

$$r = \ln(1 + i).$$

The above procedure provides the equivalent uniform series of annual system costs per career. Computation of A for each correctional alternative provides a basis for comparing the relative costs associated with each alternative.

## The Computer Program and Results

To facilitate the computations discussed in the previous section, the baseline model has been incorporated into a computer program, using the BASIC programming language. The program listing and a discussion of its components are contained in Appendix III. The program was written for use with the UNIVAC 1108 Time-Sharing System (EXEC 8). It can, however, be easily modified for use on other systems.

The program was run using the transition matrices and the cost matrix previously developed. A time horizon of 20 years was used to demonstrate the convergence of the process to steady state conditions. Results of these runs are contained in Appendix III and are summarized in Table 1 and Figure 10. The equivalent annual cost and the expected number of subsequent convictions for a 20 year horizon are shown in Table 1. Figure 10 portrays graphically, for each crime category, the expected proportion of the current prison population that will be in prison after N years as the result of conviction for the current crime or a subsequent crime.

The expected number of returns by conviction for each category represents the expected number of times that the average number of the current convicted population will be reincarcerated for commission of any subsequent crime. As shown in Table 1, those numbers are highest for burglary and larceny, the least

Table 1. Expected Number of Returns by Conviction

and Equivalent Annual Cost Per Career.

| Crime of current Incarceration | Assault | Robbery | Burglary | Larceny |
|---|---|---|---|---|
| Expected number of returns by conviction | 3.99 | 3.62 | 5.52 | 5.20 |
| Equivalent Annual Cost per Career | 913.49 | 755.50 | 1278.50 | 1110.72 |

serious of the categories and the categories which have shorter sentences.

The cost figures shown in this table are dependent upon the cost factors used to develop the cost matrix. As indicated in the development of the cost matrix, estimates were required in many cases and these estimates need considerable refinement. Thus the main purpose of the numbers in Table 1 is to show the type of results which the model produces.

## Estimating System Population

Information on first offender input to the corrections system can be used in conjunction with the outputs of the Markov model to develop estimates of future system population. These estimates are useful tools for analyzing the effects of changes in parole procedures and sentence distributions on system population and for determining future facility and manpower requirements.

Development of population estimates requires certain assumptions about

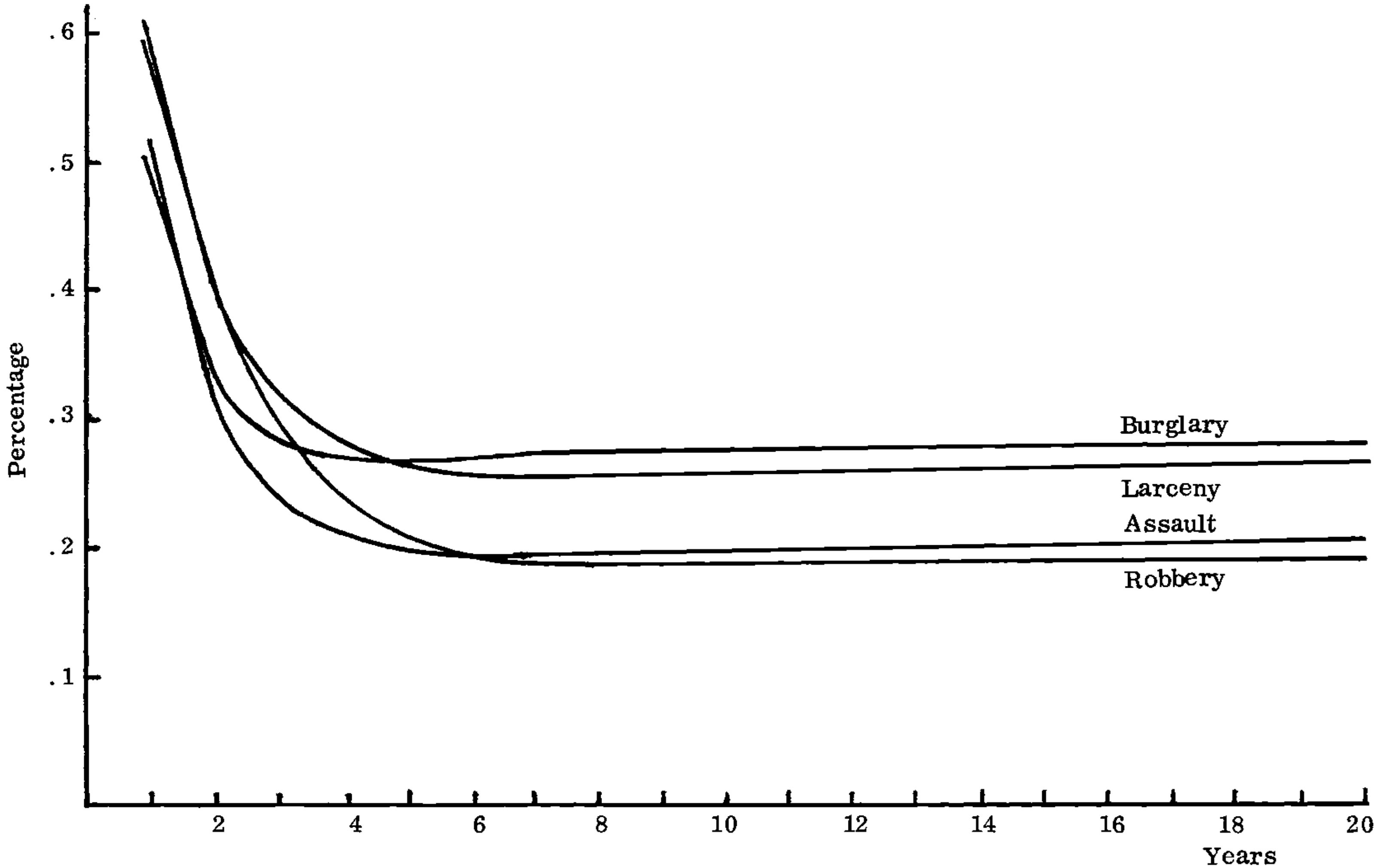


Figure 10. Expected Percentage of the Current Convicted Population that will be in Prison by Conviction after N Years, by Crime Category.

the first offender input to the system. Specifically, it must be assumed that this input will continue to follow the trends that it has followed in the past. This assumption permits the prediction of first offender input based on projection of the trend. This prediction can then be combined with the expected recidivist input generated by the Markov model to arrive at an estimate of future system populations.

The first offender input to the Georgia system for the five year period, FY 1967 through FY 1971, is listed by crime category in Table 2. This data was compiled from Bureau of Prisons Form PB-1, "Prisoner Statistics Court Admissions," and from Georgia Board of Corrections Annual Reports for the years considered.

Table 2. First Offender Input to the Georgia Corrections System, by Crime Category

| Crime Category | Assault | Burglary | Larceny | Robbery |
|---|---|---|---|---|
| 1967 | 236 | 802 | 495 | 189 |
| 1968 | 324 | 845 | 473 | 224 |
| 1969 | 315 | 710 | 578 | 210 |
| 1970 | 347 | 718 | 396 | 272 |
| 1971 | 353 | 734 | 344 | 337 |

There are several techniques available which can be used to project any trend portrayed by the data in Table 2 into the future. One of these techniques involves relating the first offender input to the total population. If it is assumed that this relation remains constant, then first offender input can be estimated from population growth data. Using this approach, the first offender input per 100,000 of population was computed and is shown in Table 3.

Table 3. First Offender Input per 100,000 Population

| Crime Category | Assault | Burglary | Larceny | Robbery |
|---|---|---|---|---|
| 1967 | 5.5 | 18.4 | 11.4 | 4.4 |
| 1968 | 7.4 | 19.2 | 10.8 | 5.1 |
| 1969 | 6.9 | 15.5 | 12.6 | 3.8 |
| 1970 | 7.5 | 15.5 | 8.6 | 5.9 |
| 1971 | 6.7 | 15.7 | 7.4 | 7.2 |
| Average | 6.8 | 15.7 | 10.2 | 5.3 |
| Average Change per Year | +.3 | -.67 | -.75 | +.7 |

Current population predictions for Georgia indicate that an average increase of 75,000 per year can be expected for the next ten years. These are the figures currently being used by the Georgia State Planning Commission. Using the above data, the first offender input for any year can be computed for each crime category as follows: Let P be the population for year n and O be the first offender input per 100,000 population. Then

$$P_n = P_{n-1} + 75,000$$

$$O_n = O_{n-1} + I$$

where I is the average change per year from Table 3. The total first offender input, FO, is then given by

$$FO_n = \frac{P_n}{100,000}(O_n)$$

The remaining portion of the prison population can be estimated using the transition matrices of the Markov model. Let

| | | |
|---|---|---|
| $POP(X)_n$ | = | the total number in prison for crime category X at the end of year n, X = A, B. L, R. |
| $IN(X)_n$ | = | the number in prison by conviction for crime category X at the end of year n. |
| $P(X)_n$ | = | the number on parole at the end of year n, whose last crime of conviction was category X. |
| $TV(X)_n$ | = | the number in prison for technical violation at the end of year n, last crime of conviction was category X. |
| $F(X)_n$ | = | the number of ex-prisoners in a free status, at the end of year n, whose last conviction was for crime category X. |

The total prison population at any time consists of the sum of those in for conviction and those in for technical violations. That is

$$POP(X)_n = IN(X)_n + TV(X)_n$$

To compute these values, the transition matrix is used to estimate the number of discharges by parole or expiration of sentence and the number of admissions by conviction or technical violation. The first offender input estimate is then added to arrive at the total population. This value is obtained by solving the following equations.

$$IN(X)_n = IN(X)_{n-1} - IN(X)_{n-1}[p_{14} + p_{12}] + P(X)_{n-1}p_{21} + F(X)_{n-i}p_{41} + FO_n$$

$$P(X)_n = P(X)_{n-1} - P(X)_{n-1}[p_{21} + p_{23}] + IN(X)_{n-1} \cdot p_{12} + TV(X)_{n-1} \cdot p_{32}$$

$$TV(X)_n = TV(X)_{n-1} - TV(X)_{n-1}[p_{34} + p_{32}] + P(X)_{n-1} p_{23}$$

$$F(X)_n = F(X)_{n-1} - F(X)_{n-1} \cdot p_{41} + IN(X)_{n-1} p_{14} + TV(X)_{n-1} p_{34} + P(X)_{n-1} \cdot p_{24}$$

$$POP(X)_n = IN(X)_n + TV(X)_n$$

where the $P_{ij}$ are the elements (i, j) of the steady state transition matrix.

The above procedures were included in the computer program discussed in Appendix III. The model was then used to develop population estimates for each crime category for a period of ten years, starting with 1972. The estimates generated are reproduced in Table 4.

Table 4. System Population Estimates, 1972-1982.

| Crime Category | Assault | Burglary | Larceny | Robbery |
|---|---|---|---|---|
| End of FY | | | | |
| 1972 | 910 | 2026 | 1061 | 888 |
| 1973 | 1000 | 2226 | 1166 | 973 |
| 1974 | 1096 | 2420 | 1261 | 1067 |
| 1975 | 1197 | 2606 | 1348 | 1169 |
| 1976 | 1303 | 2784 | 1425 | 1280 |
| 1977 | 1413 | 2955 | 1492 | 1400 |
| 1978 | 1529 | 3117 | 1549 | 1529 |
| 1979 | 1650 | 3271 | 1595 | 1667 |
| 1980 | 1777 | 3416 | 1631 | 1815 |
| 1981 | 1909 | 3552 | 1656 | 1972 |

Since FY 1972 was considered year 1, the initial values of IN, P, TV, and F that were used as inputs for the model were the values for FY 1971 (year n-1).

The values used are shown in Table 5.

Table 5. Initial Conditions for the Population Model

| Crime Category | Assault | Burglary | Larceny | Robbery |
|---|---|---|---|---|
| IN | 848 | 1896 | 932 | 1206 |
| P | 337 | 667 | 268 | 394 |
| TV | 135 | 268 | 92 | 179 |
| F | 1300 | 1700 | 1100 | 1500 |

The statistical data required to determine an exact value for F is not available for the Georgia system. The values of F shown in the table and used in the model are estimates provided by the statistical section of the Georgia Department of Offender Rehabilitation. Values for the other parameters were compiled from Bureau of Prisons Form PB-1, Bureau of Prisons Form PB-2, State Board of Pardons and Paroles Form #903, and the Georgia Board of Corrections Annual Report for FY 1971.

The numbers contained in Table 4 represent the confined population, including both those in for conviction and those in as the result of technical violation of parole. Because the model does not distinguish subsequent crimes by category, the estimates for each category represent the first offender input for that category plus those initially committed for that crime who are subsequently reincarcerated for any crime or for technical violation of parole.

As shown in Table 5, the confined population at the end of FY 1971 was 983 for assault, 2164 for burglary, 1024 for larceny and 1385 for robbery. These numbers are obtained by taking the sum of the numbers for IN and TV. Comparing these numbers with the 1981 estimates in Table 4 indicates an increase for the 10 year period of 102% for assault, 50% for burglary, 62% for larceny, and 42% for robbery. This represents an average increase of 63% for the four categories. Equivalently, it represents an average increase in confined population of 353 per year for the four categories combined.

To test the sensitivity of these numbers to the first offender input estimates, separate runs were made using a constant first offender input. The first offender input used for these additional runs was the average first offender input for each category for the years 1967-1971. Using the data in Table 2, these averages were found to be 315 for assault, 760 for burglary, 457 for larceny, and 246 for robbery. Using these values the results in Table 6 were obtained.

Table 6. System Population Estimates with Constant First Offender Input

| | Assault | Burglary | Larceny | Robbery |
|---|---|---|---|---|
| 1972 | 1287 | 2055 | 1655 | 1086 |
| 1973 | 1359 | 2284 | 1782 | 1134 |
| 1974 | 1430 | 2513 | 1909 | 1182 |
| 1975 | 1501 | 2743 | 2037 | 1231 |
| 1976 | 1573 | 2972 | 2164 | 1279 |
| 1977 | 1644 | 3201 | 2292 | 1327 |
| 1978 | 1715 | 3430 | 2419 | 1375 |
| 1979 | 1787 | 3659 | 2546 | 1423 |
| 1980 | 1858 | 3888 | 2674 | 1471 |
| 1981 | 1929 | 4117 | 2801 | 1519 |

To aid comparison of Table 6 with Table 4, the per cent increase for the 10 year period for each case is shown in Table 7.

Table 7. Comparison of System Population Estimates

| | Assault | Burglary | Larceny | Robbery |
|---|---|---|---|---|
| 10 Year Increase, First Offender Input Based on Total Population | 102% | 50% | 62% | 42% |
| 10 Year Increase, First Offender Input Held Constant | 106% | 90% | 174% | 9.7% |

This table points out the sensitivity of system population estimates to first offender input. For example, extrapolating current trends yields large increases resulting from larceny convictions but small increases from burglary convictions; the latter resulting from a decrease in first offenders. It is evident, therefore, that additional research is required to be able to estimate first offender input reliably. The objective of developing the numbers contained in Tables 4 and 6 was to demonstrate that if accurate input data is available, the methodology developed in this thesis can be used for estimating the effect of alternative programs on system population.

## Model Validation

As defined by Van Horn (63), validation is the process of building an acceptable level of confidence that an inference about a simulated system is a correct or valid inference for the actual system. According to Van Horn, this process will seldom, if ever, result in "proof" that the model is a correct or "true" model of the real system. Fortunately, the user of the model is seldom concerned with proving the "truth" of the model. Instead, the model produces some specific insights which need validation. Thus the objective of the validation problem is to verify a specific set of insights, not necessarily the mechanism that generated the insights. A convenient method of verifying these insights is by comparing input-output transformations.

As can be seen from Table 1, the model indicates that those prisoners incarcerated for burglary have the highest return rate, followed in order by those convicted for larceny, assault, and robbery. Although data to verify this output is not available for Georgia, such data is available on a national basis in the FBI Careers in Crime file (75). This file has been active for only ten years, and does not, therefore, contain the number of returns to prison for a 20 year horizon. Information currently in the file does, however, indicate that, for those returned to prison three or more times, those originally convicted for burglary have the highest return rate, followed in order by those convicted for larceny, assault and robbery. Similar findings were reported by the National Commission on the Causes and Prevention of Violence (11, p. 558). These comparisons indicate that the frequency of return by crime type predicted by the model corresponds to the frequency of return pattern of the actual system. The statistics required to determine the accuracy of the expected number of returns predicted are not available.

Although not generated as outputs, there are other parameters which can be computed from the model and compared with corresponding parameters of the real system. Two such parameters are the average sentence length for the initial conviction. In terms of the Markov model, these parameters are equivalent to the mean first passage time from state IN(C) to state OUT(D) and the average holding time in state IN(C), respectively. The values of these parameters were computed using the computational procedures discussed in Chapter II and are shown in columns 1 and 3 of Table 3. Average sentence length and average time served for the Georgia system were obtained from statistical reports submitted to the National Bureau of Prisons on Form PR-1. These values are shown in columns 2 and 4 of Table 8.

Table 8. Average Sentence Length and Average Time Served (Years).

| Crime Category | Mean First Passage Time, IN(C) to OUT(D) | Average Sentence | Average Holding Time, IN(C) | Average Time Served |
|---|---|---|---|---|
| Assault | 6.6 | 5.6 | 2.04 | 2.61 |
| Robbery | 8.7 | 8.25 | 2.51 | 2.77 |
| Burglary | 5.65 | 4.75 | 2.0 | 2.25 |
| Larceny | 6.9 | 5.35 | 2.44 | 2.87 |

As a further check on the model, the average holding times and the expected number of returns can be used to compute the average time to recidivate.

Performing this computation gives the values shown in Table 9.

Table 9. Predicted Average Time to Recidivate (Years).

| Crime Category | Assault | Robbery | Burglary | Larceny |
|---|---|---|---|---|
| Average time to recidivate | 3 | 3.56 | 1.63 | 1.15 |

These values compare favorably with those reported by Johnston (36). He reported an average time to recidivate of 2 years for assault, 3 years for robbery, and 1.5 years for burglary and larceny. Johnston did not include manslaughter in the category of assault nor did he include larceny of motor vehicle in the larceny category, as was done for this model.

Table 10 compares actual confined population figures for the years 1966-1970 with confined population estimates produced by the model for those same years. The estimates were developed using first offender input based on total population growth estimates for Georgia.

As indicated by the table, the model does not identify large fluctuations that may occur from year to year. However, over the entire period, the estimated and actual populations compare favorably, suggesting that the model does in fact produce relatively accurate population estimates.

Comparison of Table 10 with Table 2 reveals that, although first offender input for burglary and larceny decreased over the five year period, total population for these two categories increased. This implies that either the number of

Table 10. Comparison of Actual and Estimated Populations

| Crime Category | Assault True | Assault Pred | Burglary True | Burglary Pred | Larceny True | Larceny Pred | Robbery True | Robbery Pred |
|---|---|---|---|---|---|---|---|---|
| End of FY | | | | | | | | |
| 1966 | 754 | 756 | 1962 | 1904 | 1290 | 1338 | 603 | 637 |
| 1967 | 1025 | 827 | 2090 | 2083 | 1382 | 1428 | 709 | 708 |
| 1968 | 961 | 904 | 2240 | 2267 | 1477 | 1505 | 641 | 787 |
| 1969 | 1128 | 983 | 2162 | 2407 | 1560 | 1536 | 889 | 873 |
| 1970 | 1072 | 1067 | 2339 | 2515 | 1656 | 1602 | 1092 | 967 |

recidivists increased or the number of technical violators increased. A check of the records for the period shows that the number of recidivists committed to the system (for all crimes) increased by seven percent.

The data in Table 10 also indicates that the rate of increase for the estimated burglary population is slightly higher than the rate of increase in the actual burglary population. This suggests that perhaps the national data used for row 4 of the burglary transition matrix is not truly representative of the Georgia data. However, because the data required to develop this row of the matrix is not available for Georgia, the national data had to be used.

Ideally, the data used to develop the model should not have been used for validation. Instead, data from another time period or different data for the same time period should have been used. If time had been available, this data would have been collected and used. If further research is conducted in this area, the future data should be used to verify the outputs of the model.

# CHAPTER IV

# EXAMPLES OF THE USE OF THE METHODOLOGY

## Information Requirements

Use of the model developed in Chapter III to evaluate correctional alternatives requires that statistical information about the alternatives be available. Specifically, the user of the model must know the effect the alternative will have on the transition probabilities and on the costs associated with each of the possible transitions. This knowledge is then used to develop transition and cost matrices for the alternative under consideration. These matrices then become the input for the Markov model of the alternative. The outputs generated by the model provide the basis for determining the merit of the alternative relative to existing programs or relative to other alternatives being considered.

The required information can be obtained using any of a variety of techniques, such as pilot programs, controlled experimentation, or psychological testing and prediction. The costs associated with each of these techniques and the accuracy of the data produced by each vary considerably. Additionally, some of the techniques will produce usable statistics within a very short period of time, while others may require a period of several years to produce the same data. The decision as to which technique to employ must be based on a thorough analysis of the availability of funds for information gathering, the degree of accuracy required, and the degree of urgency associated with the information gathering process.

The value of this type of information, as well as the use of the model, can be illustrated with some hypothetical test cases. The remainder of this chapter will be devoted to an analysis of four such test cases. The first two cases illustrate the effect of implementing new programs designed to reduce the probability of reincarceration, while the last two illustrate the effect of changes in parole policies. The crime category selected for use in each test case is the category of burglary.

## Analysis of New Programs

The first two hypothetical test cases can be developed as follows. Suppose that test case 1 involves an expansion of the current prison industries program. Assume that this expansion includes training that will provide the inmate with an accredited skill upon discharge, thus increasing his opportunity for employment. Further assume that participation in this program will result in an expected reduction of five per cent in the probability of reconviction, i.e., a reduction from 0.22 to 0.17. Let test case 2 consist of a further expansion of the prison industries program to include the incorporation of job placement service. Assume that this additional service will reduce the probability of reconviction by another five per cent to .12. The transition matrices for each of the test cases are then as shown in Figures 11 and 12.

With these transition matrices, the expected number of returns by conviction is 4.69 for test case 1, a reduction of 15%, and 3.68 for test case 2, a drop of 33.3%. (See Appendix IV for computer results.) The change in the

| | State 1 IN(C) | State 2 OUT(P) | State 3 IN(TV) | State 4 OUT(D) |
|---|---|---|---|---|
| State 1--IN(C) | .502 | .242 | 0 | .256 |
| State 2--OUT(P) | .062 | .325 | .093 | .520 |
| State 3--IN(TV) | 0 | .116 | .626 | .258 |
| State 4--OUT(D) | (.17) | 0 | 0 | (.83) |

Figure 11. Transition Matrix for Test Case 1

(Crime Category is Burglary)

| | State 1 IN(C) | State 2 OUT(P) | State 3 IN(TV) | State 4 OUT(D) |
|---|---|---|---|---|
| State 1--IN(C) | .502 | .242 | 0 | .256 |
| State 2--OUT(P) | .062 | .325 | .093 | .520 |
| State 3--IN(TV) | 0 | .116 | .626 | .258 |
| State 4--OUT(D) | (.12) | 0 | 0 | (.88) |

Figure 12. Transition Matrix for Test Case 2.

(Crime Category is Burglary)

expected percentage of the current population that will be in prison at any time because of conviction is shown in Figure 13. As the figure indicates, the steady state probability drops from .276 for the current system to 0.235 for test case 1 and 0.184 for test case 2.

Any program which would produce the results indicated for these examples would almost certainly increase the yearly cost of incarceration. Since the cases

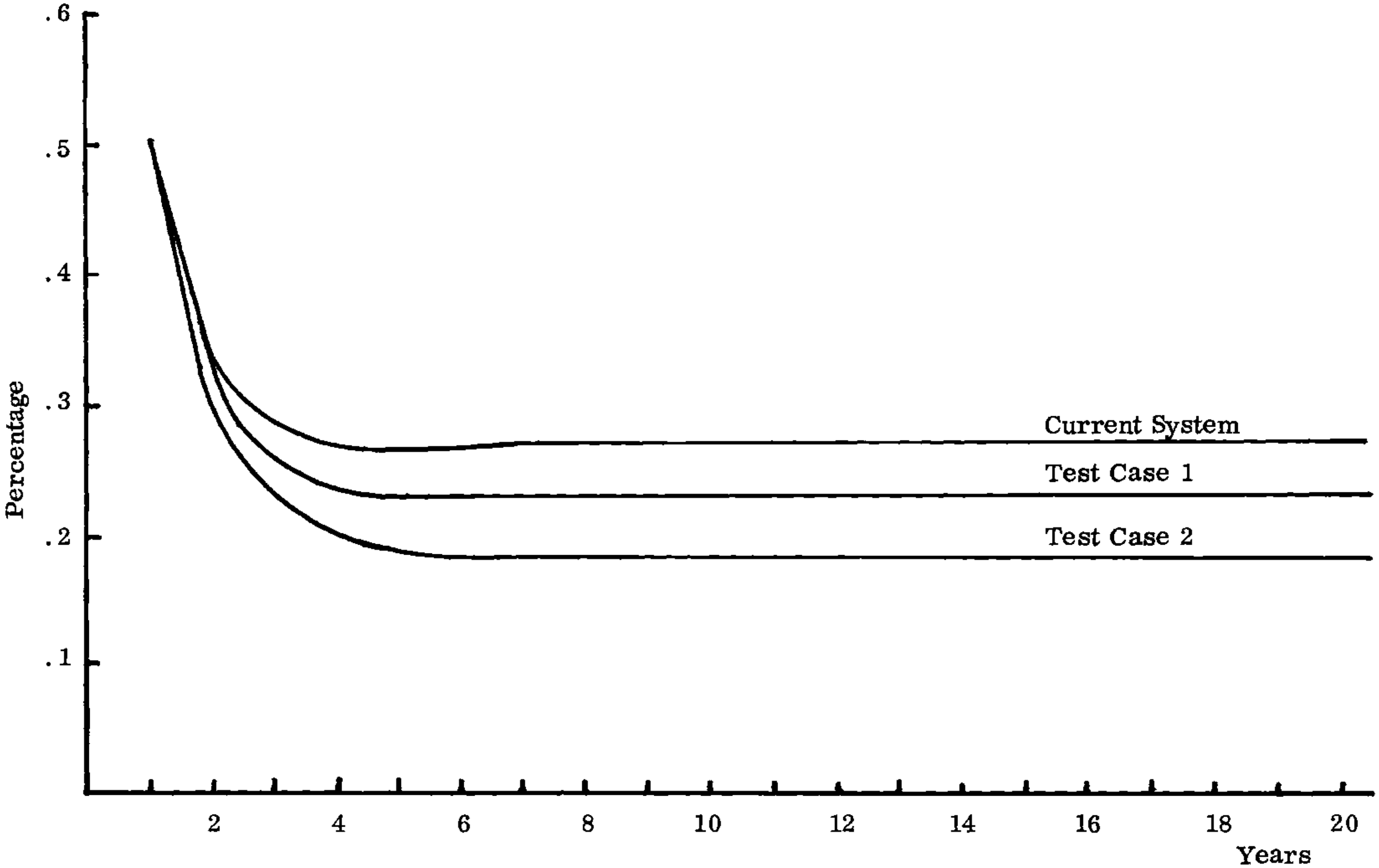


Figure 13. Expected Percentage of the Convicted Population that will be in Prison by Conviction after N Years. (Crime Category is Burglary)

discussed are strictly hypothetical, it would be unrealistic to attempt to assign an absolute cost to either case. In the analysis of an actual program, these costs, or at least reasonable estimates, could be obtained. A cost matrix for the proposed program would then be constructed for use in the model.

Another approach is to use the model to conduct "break-even" analysis. The objective of the "break-even" analysis is to determine by how much a program can increase the cost of incarceration without increasing the equivalent annual cost per career. To do this, a cost matrix similar to that in Figure 14 is constructed. The quantity X in this matrix represents the allowable increase

$$
\begin{array}{cc}
 & \begin{array}{cccc} \text{IN(C)} & \text{OUT(P)} & \text{IN(TV)} & \text{OUT(D)} \end{array} \\
\begin{array}{c} \text{IN(C)} \\ \text{OUT(P)} \\ \text{IN(TV)} \\ \text{OUT(D)} \end{array} &
\begin{bmatrix}
2890.80 + X & 1856.12 + X/2 & 0 & 1270.4 + X/2 \\
6226.12 + X/2 & 621.44 & 1906.12 + X/2 & 60.72 \\
 & 1856.12 + X/2 & 2890.80 + X & 1270.4 + X/2 \\
5647.40 + X/2 & 0 & 0 & -550.00
\end{bmatrix}
\end{array}
$$

Figure 14. Cost Matrix for Break Even Analysis.

(Crime Category is Burglary)

in the annual cost of incarceration. Starting with the equivalent annual cost for the current system, the reverse of the procedure for cost computation presented in Chapter III is used to solve for the value of X.

The same result can be obtained by selecting an initial arbitrary value of X to use as the input for the computer program. This value is then incremented until successive values of the equivalent annual cost bracket the equivalent annual cost for the current system. Once this bracket is established, the size of the increment is iteratively reduced by one-half in the appropriate direction. This procedure converges to a solution very quickly. Since the program requires only a few milliseconds of central processor time, this technique provides the break even cost quickly and inexpensively.

Using the above procedure, the break-even cost for test cases 1 and 2 were found to be \$894.00 and \$1664.00, respectively. Thus, a program that reduces the probability of reincarceration by five percent can increase the annual cost of incarceration by as much as \$894.00 without increasing the total equivalent annual cost per career. Similarly, a program that reduces the probability of reincarceration by ten percent can increase the annual cost of incarceration by as much as \$1664.00 without increasing the total equivalent annual cost.

To further illustrate the use of the model for cost analysis, assume that the program costs are known and that test case 1 would increase the yearly cost of incarceration by \$1000. Then the cost matrix for test case 1 would be as shown in Figure 15. Further assume that implementation of the program for

| | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| IN(C) | 3990.90 | 2356.12 | 0 | 1770.4 |
| OUT(P) | 6726.12 | 621.44 | 2406.12 | 60.72 |
| IN(TV) | 0 | 2356.12 | 3990.90 | 1770.40 |
| OUT(D) | 6147.40 | 0 | 0 | -550 |

Figure 15. Cost Matrix for Test Case 1.

test case 2 would result in an additional increase of $500 in the yearly cost of incarceration. This increase gives the cost matrix shown in Figure 16 for test case 2. Using these cost matrices as inputs to the model, the equivalent annual

| | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| IN(C) | 4490.80 | 2606.12 | 0 | 2020.40 |
| OUT(P) | 6976.12 | 621.44 | 2656.12 | 60.72 |
| IN(TV) | 0 | 2606.12 | 4490.80 | 2020.40 |
| OUT(D) | 6397.40 | 0 | 0 | -550.00 |

Figure 16. Cost Matrix for Text Case 2.

cost is $1347.13 for test case 1 and $1153.72 for test case 2, as compared to $1278.50 for the existing system. Thus, although test case 1 increases the annual cost of incarceration by $1000, the long range equivalent annual cost increases by only $68 per criminal. Test case 2, which increases the annual cost of incarceration by $1500 over the cost for the current system, results in a long range savings of $125 per criminal per year. These cost figures, together with the expected number of returns by conviction and the steady state probability of being in prison by conviction, are measures that can be used to establish the relative merit of alternative programs.

Another measure that can be used in comparing alternative programs is the effect each program has on the estimated system population. Using the first offender input estimates based on total population growth and the transition matrices of the hypothetical test cases developed in this chapter, population estimates for each of the test cases were developed. The results are contained in Table 11.

Table 11. System Population Estimates--Test Cases 1 and 2.

(Crime Category is Burglary)

| | Current System | Test Case 1 | Test Case 2 |
|---|---|---|---|
| End of FY: | 2026 | 1835 | 1597 |
| 1972 | 2026 | 1835 | 1597 |
| 1973 | 2226 | 2000 | 1724 |
| 1974 | 2420 | 2162 | 1846 |
| 1975 | 2606 | 2317 | 1963 |
| 1976 | 2784 | 2466 | 2075 |
| 1977 | 2955 | 2607 | 2181 |
| 1978 | 3117 | 2742 | 2282 |
| 1979 | 3271 | 2869 | 2376 |
| 1980 | 3416 | 2988 | 2465 |
| 1981 | 3552 | 3100 | 2545 |

As indicated by the data in this table, reducing the probability associated with reconviction from 22% to 17% reduces the expected system population for the category of burglary by 13% after tenyears. Reducing the probability from 22% to 12% results in a 28% reduction in the expected system population for the burglary category at the end of ten years.

## Analysis of Parole Policies

The methodology developed in Chapter III can also be used to predict the effect on system costs, recidivism, and system population of changes in parole policies. As indicated earlier in this chapter, one must know how such policy changes affect the transition matrices in order to conduct such an analysis.

To illustrate this use of the model, two additional test cases were developed for the crime category of burglary. In test case 3, the probabilities associated with the transition from a confined status to a parole status were increased by five percent, i.e., $p_{12}$ was increased from 0.242 to 0.292 and $p_{32}$ was increased from 0.116 to 0.166. In terms of the data presented in Appendix I, this increase would represent an average increase of 100 per year in the number of convicted prisoners paroled. Since the elements of each row of the matrix must sum to one, a five percent increase in one element of row 1 and row 3 must be accompanied by a corresponding decrease distributed over the remaining elements of each row. Assume the decrease is distributed equally between the remaining elements. Then the transition matrix for test case 3 is as shown in Figure 17.

$$
\begin{array}{l c}
 & \begin{array}{cccc} \text{IN(C)} & \text{OUT(P)} & \text{IN(TV)} & \text{OUT(D)} \end{array} \\
\begin{array}{l} \text{IN(C)} \\ \text{OUT(P)} \\ \text{IN(TV)} \\ \text{OUT(D)} \end{array} &
\begin{bmatrix}
(.477) & (.292) & 0 & (.231) \\
(.087) & (.300) & (.118) & (.495) \\
0 & (.166) & (.601) & (.233) \\
.220 & 0 & 0 & .780
\end{bmatrix}
\end{array}
$$

Figure 17. Transition Matrix for Test Case 3

(Crime Category is Burglary)

In test case 4, the parole rate was decreased by five percent, that is the values of $p_{12}$ and $p_{32}$ were decreased to 0.192 and 0.066, respectively. As in the previous example, this change must be accompanied by a corresponding increase in the other elements of the row affected. Thus the transition matrix for test case 4 is as shown in Figure 18.

$$
\begin{array}{l c}
 & \begin{array}{cccc} \text{IN(C)} & \text{OUT(P)} & \text{IN(TV)} & \text{OUT(D)} \end{array} \\
\begin{array}{l} \text{IN(C)} \\ \text{OUT(P)} \\ \text{IN(TV)} \\ \text{OUT(D)} \end{array} &
\begin{bmatrix} (.527) & (.192) & 0 & (.281) \\ (.037) & (.350) & (.075) & (.545) \\ 0 & (.066) & (.651) & (.283) \\ .220 & 0 & 0 & .780 \end{bmatrix}
\end{array}
$$

Figure 18. Transition Matrix for Test Case 4.

(Crime Category is Burglary)

The changes in row 2 of the transition matrices for test cases 3 and 4 resulted from the nature of the change in parole policy illustrated by these examples. In both cases, the average sentence length was held constant, that is the mean first passage time from state IN(C) to state OUT(D) was not allowed to vary. This, in effect, keeps the minimum time to parole eligibility constant so that an increase or decrease in the number paroled reflects a change in the risk criteria used in granting parole. This change in risk criteria causes a corresponding change in both the probability of a technical violation and the probability of commiting a new crime while on parole. Changes in these probabilities necessitates computation of new values for row 2 of each transition matrix. The changes shown in row 2 of the matrices in Figures 17 and 18 are completely arbitrary, their intended use being only to illustrate this particular application of the model.

Using these transition matrices and the cost matrix for the baseline model, the results shown in Table 12 were obtained.

Table 12. The Effect of Changing the Parole Rate

(Crime Category is Burglary)

| | Current System | Test Case 3 | Test Case 4 |
|---|---|---|---|
| Expected no. of returns by conviction | 5.52 | 5.64 | 5.09 |
| Equivalent annual cost | 1278.50 | 1270.20 | 1303.89 |
| Steady state for IN(C) | .276 | .262 | .274 |
| System Population after 10 yrs. | 3552 | 3476 | 3747 |

In test case 4, the percentage of paroles granted each year was reduced by five percent. As indicated in Table 12, this change reduces the expected number of returns by conviction by 7.5% when compared to the existing system. The price of this reduction in recidivism is reflected by the predicted 1.7% increase in equivalent annual cost per career and the predicted 5.7% increase in system population for this category and a ten year horizon. The increase in cost and population is directly attributable to the increase in the average time spent in prison that results from decreasing the probability of parole. (The average holding time for test case 4 is 2.12 years, as compared to 2.0 years for the existing system.)

These results clearly show that recidivism rates can be reduced by increasing the average time served per conviction. The question that Criminal Justice administrators must answer is whether or not this is the best way to achieve these results. By using the methodology developed in Chapter III to analyze alternatives, the answer to this question can be found by comparing the model generated costs and benefits of each alternative.

For example, the program of test case 1 resulted in 4.69 expected returns by conviction, an equivalent annual cost per career of $1347.13, and a system population of 3100 after ten years for the crime category of burglary. Comparison of these results with the results of test case 4 shows that test case 1 produces a larger decrease in the expected number of returns, a slightly higher equivalent annual cost, and a significantly lower system population after ten years. This comparison suggests that a program of the type hypothesized in test case 1 would be preferred to a program of the type hypothesized in test case 4.

The effect of increases or decreases in sentence length could also be shown by constructing test cases similar to those just analyzed. However, since parole eligibility is determined, in part, by the sentence length and because of the structure of the transition matrices, such test cases would yield results very similar to those of test cases 3 and 4. An increase in sentence length affects the transition matrix in the same way that a decrease in parole rate affects it, although the magnitude of the variations may be different. Similarly, a decrease in sentence length would have basically the same effect as increasing the parole rate. Because of these similarities, the analysis of test cases 3 and 4 is considered sufficient to illustrate the use of the model for this type of analysis.

## Summary

The test cases analyzed in this chapter illustrate how the model developed in Chapter III can be used to generate quantitative measures of effectiveness for correctional alternatives. Test cases 1 and 2 were designed to illustrate the use of the model in evaluating proposed programs, while test cases 3 and 4 were designed to illustrate the use of the model for evaluating changes in existing parole policies. The use of the model outputs for cost-benefit analysis was discussed and illustrated. A technique for conducting "break-even" analysis was presented and illustrated. The analysis of each test case was based on hypothetical situations, designed for illustrative purposes only.

# CHAPTER V

## CONCLUSIONS AND RECOMMENDATIONS

This research has resulted in the development of a methodology that uses quantitative techniques for predicting the effectiveness of correctional programs. The methodology produces measures that can be used for comparative evaluation of the probable costs and results of each alternative.

Development of the methodology and illustrations of some of its applications were based on sample data compiled from records maintained by the Georgia Department of Offender Rehabilitation. The numerican results are illustrative in nature. Since these results are dependent upon the data input, estimates used in this thesis should either be replaced by data of greater accuracy before the methodology is integrated into the decision making process.

The model can be refined in several areas. The transition matrices, in their present form, do not take into account that probability of arrest and average sentence length may vary according to the number of prior convictions. Additional research should be conducted to determine the relationships between prior convictions and probability of arrest and sentence length.

Refinement in the cost factors are imperative if results that can be used for meaningful cost/benefit analysis are to be obtained. Specifically, such refinements should include consideration of welfare costs, contributions to the economy of parolees, and more accurate figures for the cost of crime.

The methodology illustrates one technique for estimating future system populations. Overcrowded conditions in correctional institutions throughout the country clearly indicate the need for such estimates in planning future facility and manpower requirements. The technique developed in this thesis is sensitive to changes in first offender input. Because of this sensitivity, refinement is needed in procedures for predicting the first offender input.

The hypothesis that the Markov assumption is applicable to corrections system is critical to the development of the methodology. Although some validation was attempted, a conclusive test of this hypothesis requires some sophisticated statistical testing. Such tests require the use of data not available in the present records system.

Further refinements should include procedures for identifying the nature of subsequent crimes committed by recidivists. These refinements could take the form of an expanded transition matrix or incorporation of crime switch matrices of the type proposed by Blumstein into the methodology.

# APPENDIX I

## DATA FOR THE TRANSITION MATRICES

This appendix contains the raw data used to develop the transition matrices for the baseline model. Data for rows 1, 2, and 3 of each matrix was compiled from statistical records of the Georgia Board of Corrections and the State Board of Pardons and Paroles. The specific sources used were: Bureau of Prisons Form PR-1, "Prisoner Statistics Court Admissions"; Bureau of Prison Form PR-2, "Prisoner Statistics Releases"; Bureau of Prisons Form PR-3, "Movement of Sentenced Population Summary"; State Board of Pardons and Paroles Form #903, "Monthly Statistical Report"; informal records maintained for the convenience of members of the State Board of Pardons and Paroles; and Georgia Board of Corrections Annual Reports.

Data was compiled for Fiscal Years 1967 through 1971 for felons convicted of the four crime categories considered. The values of the individual elements of each matrix are the average percentages for the five year period.

Data for row 4 of the matrices is not available for the state of Georgia. The values used for element $p_{41}$ were taken from the study by Mahoney and Blozan (44). The element $p_{44}$ is simply one minus $p_{41}$. Values for $p_{44}$ are as shown in Table A-1-1.

Table A.I.1. $p_{41}$ of the Transition Matrices for the Baseline Model

| Crime of Release | Assault | Robbery | Burglary | Larceny |
|---|---|---|---|---|
| Fraction Returned for Any Crime w/i 1 year after Release | .13 | .09 | .22 | .16 |

Source: Mahoney and Blozan (44).

Data used to compute rows 1, 2, and 3 of each of the transition matrices for the baseline model is shown in the following tables.

Table A. I. 2. Data for Row 1 of the Assault Transition Matrix

| | Convicted Prisoners Confined, Start of FY | Paroled During FY | Discharged During FY |
|---|---|---|---|
| 1967 | 641 | 203 | 141 |
| 1968 | 872 | 198 | 174 |
| 1969 | 817 | 282 | 168 |
| 1970 | 959 | 252 | 184 |
| 1971 | 911 | 273 | 165 |
| Five year Average | | 28.8% | 19.8% |

From Table A.I.2, $p_{12} = .288$ and $p_{14} = .198$; $p_{11} = 1 - .288 - .198 = .514$.

Table A.I.3. Data for Row 2 of the Assault Transition Matrix

(Last Conviction for Assault)

| | Parole Pop., Start of FY | Convicted for new Crime in FY | Technical Violations | Parolees Discharged |
|---|---|---|---|---|
| 1967 | 242 | 18 | 27 | 94 |
| 1968 | 211 | 16 | 23 | 96 |
| 1969 | 220 | 20 | 28 | 142 |
| 1970 | 263 | 22 | 31 | 176 |
| 1971 | 213 | 22 | 32 | 117 |
| Five year Average | | 8.5% | 12.3% | 54.4% |

From Table A.I.3, $p_{21} = .085$; $p_{23} - .123$; $p_{24} = .544$; $p_{22} = 1 - (p_{21} + p_{23} + p_{24})$ $= .248$.

Table A.I.4. Data for Row 3 of the Assault Transition Matrix

(Last Conviction for Assault)

| | Technical Violators Confined, Start of FY | Tech. Viol. Paroled | Tech. Viol. Discharged |
|---|---|---|---|
| 1967 | 113 | 15 | 23 |
| 1968 | 153 | 17 | 41 |
| 1969 | 144 | 21 | 38 |
| 1970 | 169 | 19 | 42 |
| 1971 | 161 | 22 | 36 |
| Five year Average | | 12.7% | 24.3% |

From Table A.I.4, $p_{32} = .127$; $p_{34} = .243$; $p_{33} = .63$.

Table A.I.5. Data for Row 1 of the Burglary Transition Matrix

| | Convicted Prisoners Confined, Start of FY | Paroled During FY | Discharged During FY |
|---|---|---|---|
| 1967 | 2170 | 417 | 578 |
| 1968 | 2280 | 472 | 548 |
| 1969 | 1838 | 516 | 485 |
| 1970 | 1989 | 458 | 517 |
| 1971 | 1896 | 498 | 481 |
| Five year Average | | 24.2% | 25.6% |

From Table A.I.5, $p_{12} = .242$, $p_{14} = .256$, $p_{11} = .502$

Table A.I.6. Data for Row 2 of the Burglary Transition Matrix

(Last Conviction for Burglary)

| | Parole Pop. Start of FY | Convicted for New Crime | Technical Violators | Parolees Discharged |
|---|---|---|---|---|
| 1967 | 823 | 48 | 73 | 319 |
| 1968 | 716 | 34 | 50 | 326 |
| 1969 | 495 | 43 | 52 | 319 |
| 1970 | 544 | 35 | 59 | 365 |
| 1971 | 441 | 28 | 46 | 242 |
| Five year Average | | 6.2% | 9.3% | 52% |

Table A.I.7. Data for Row 3 of the Burglary Transition Matrix

(Last Conviction for Burglary)

| | Technical Violators Confined, Start of FY | Tech. Viol. Paroled | Tech. Viol. Discharged |
|---|---|---|---|
| 1967 | 390 | 24 | 98 |
| 1968 | 402 | 28 | 112 |
| 1969 | 324 | 56 | 78 |
| 1970 | 350 | 57 | 91 |
| 1971 | 334 | 44 | 86 |
| Five year Average | | 11.6% | 25.8% |

From Table A.I.7, $p_{32} = .116$; $p_{34} = .258$; $p_{33} = .626$

Table A.I.8. Data for Row 1 of the Robbery Transition Matrix

| | Convicted Prisoners Confined, Start of FY | Paroled During FY | Discharged During FY |
|---|---|---|---|
| 1967 | 512 | 110 | 108 |
| 1968 | 603 | 142 | 120 |
| 1969 | 545 | 172 | 118 |
| 1970 | 756 | 110 | 156 |
| 1971 | 1265 | 174 | 231 |
| Five year Average | | 19.2% | 19.9% |

From Table A.1.8, $p_{12} = .192$; $p_{14} = .199$; $p_{11} = .609$

Table A.I.9. Data for Row 2 of the Robbery Transition Matrix

(Last Conviction for Robbery)

| | Parole Pop. Start of FY | Convicted for New Crime | Technical Violators | Parolees Discharged |
|---|---|---|---|---|
| 1967 | 194 | 12 | 19 | 75 |
| 1968 | 169 | 9 | 13 | 86 |
| 1969 | 147 | 13 | 16 | 94 |
| 1970 | 206 | 17 | 24 | 138 |
| 1971 | 294 | 9 | 16 | 161 |
| Five year Average | | 5.9% | 8.7% | 54.9% |

Table A.I.10. Data for Row 3 of the Robbery Transition Matrix

(Last Conviction for Robbery)

| | Technical Violators Confined, Start of FY | Tech. Viol. Paroled | Tech. Viol. Discharged |
|---|---|---|---|
| 1967 | 91 | 11 | 23 |
| 1968 | 106 | 13 | 28 |
| 1969 | 96 | 17 | 19 |
| 1970 | 133 | 9 | 22 |
| 1971 | 222 | 12 | 47 |
| Five year Average | | 9.6% | 21.5% |

Table A.I.11. Data for Row 1 of the Larceny Transition Matrix

| | Convicted Prisoners Confined, Start of FY | Paroled During FY | Discharged |
|---|---|---|---|
| 1967 | 1343 | 195 | 293 |
| 1968 | 1260 | 211 | 273 |
| 1969 | 1497 | 275 | 328 |
| 1970 | 1096 | 244 | 219 |
| 1971 | 632 | 226 | 122 |
| Five Year Average | | 19.8% | 21.2% |

Table A.I.12. Data for Row 2 of the Larceny Transition Matrix

(Last Conviction for Larceny)

| | Parole Pop. Start of FY | Convicted for New Crime | Technical Violators | Parolees Discharged |
|---|---|---|---|---|
| 1967 | 508 | 26 | 38 | 197 |
| 1968 | 443 | 21 | 28 | 183 |
| 1969 | 403 | 12 | 19 | 260 |
| 1970 | 300 | 23 | 32 | 201 |
| 1971 | 147 | 15 | 24 | 81 |
| Five Year Average | | 5.4% | 7.8% | 51.2% |

Table A.I.13. Data for Row 3 of the Larceny Transition Matrix

(Last Conviction for Larceny)

| | Technical Violators Confined, Start of FY | Tech. Viol. Paroled | Tech. Viol. Discharged |
|---|---|---|---|
| 1967 | 237 | 15 | 63 |
| 1968 | 222 | 19 | 52 |
| 1969 | 264 | 26 | 61 |
| 1970 | 194 | 24 | 51 |
| 1971 | 112 | 15 | 29 |
| Five year Average | | 9.6% | 24.9% |

# APPENDIX II

## DATA FOR THE COST MATRIX

This appendix contains the cost data used to develop the cost matrix for the baseline model. This data was obtained from annual reports of the Georgia Board of Corrections, biennial reports of the State Board of Pardons and Paroles, and state auditor reports. Data for some elements of the matrix are estimates provided by the staffs of the Board of Corrections and the Board of Pardons and Paroles. Estimates were necessary in some cases because current cost accounting procedures do not specifically identify all costs pertinent for this model. These estimates are identified where used.

The cost of reincarceration for a new crime involves the cost of the crime itself plus the cost of arrest and conviction. Because of the scarcity of this type of data (discussed in detail in Chapter II), the data used for this model was taken from the Report of the President's Commission on Law Enforcement and the Administration of Justice (52, p. 63). For computation of elements $C_{21}$ and $C_{41}$, the average costs over all crime types were used. Data used to compute these averages is reproduced in Table A. II. 1.

Table A. II. 1. Average Cost per Subsequent Crime

| | Average Cost of the Crime | Average Cost to Arrest and Convict | Total Average Cost per Crime |
|---|---|---|---|
| Homicide | 4900 | 5100 | 10000 |
| Rape | 1300 | 2000 | 3300 |
| Robbery | 1200 | 2600 | 3800 |
| Assault | 920 | 1800 | 2730 |
| Burglary | 700 | 3100 | 3800 |
| Larceny | 660 | 3500 | 4160 |
| Auto Theft | 760 | 2800 | 3560 |
| Average Cost per Crime Over all Crime Types | | | 4477 |

Other cost factors used in the model are as follows:

| | |
|---|---|
| Cost of incarceration per inmate per year: | 2890. 80 |
| Cost of parole per parolee per year: | 621. 44 |
| Cost to administer parole proceedings (est): | 100. 00 |
| Cost to discharge from prison (est): | 100. 00 |
| Cost to discharge from parole (est): | 25. 00 |
| Cost to reincarcerate for technical violation: | 150. 00 |
| Contribution to state economy per ex-prisoner (est): | 550. 00 |
| Cost to reincarcerate for new crime (Table A. II. 1): | 4477. 00 |

Using the above cost data, the specific elements of the cost matrix were computed as follows:

$$C_{12} = 100 + 1/2(2890.80) + 1/2(621.44) = 1856.12$$

$C_{14} = 100 + 1/2(2890.80) - 1/2\ (550) = 1270.40$

$C_{21} = 4477 + 1/2(621.44) + 1/2(2890.80) = 6226.12$

$C_{23} = 150 + 1/2(621.44) + 1/2(2890.80) = 1906.12$

$C_{24} = 25 + 1/2(621.44) - 1/2(550) = 60.72$

$C_{32} = 100 + 1/2(2890.80) + 1/2(621.44) = 1856.12$

$C_{34} = 100 + 1/2(2890.80) - 1/2(550) = 1270.40$

$C_{41} = 4477 + 1/2(2890.80) - 1/2(550) = 5647.40$

# APPENDIX III

## COMPUTER LISTING

## AND BASELINE RESULTS

```
1 REM THIS PROGRAM REPRESENTS A MARKOV MODEL OF A STATE CORRECTIONS
2 REM SYSTEM.  INFORMATIONAL REMARKS AND INSTRUCTIONS ARE INTER-
3 REM SPERSED THROUGHOUT THE PROGRAM TOASSIST THE USER.
4 REM LINES 10 AND 11 IDENTIFY PROGRAM OUTPUTS.
5 REM ENTER CRIME CATEGORY CONSIDERED IN LINE 11.
10 PRINT'                         OUTPUT FOR CRIME CATEGORY OF'
11 PRINT TAB(24);'BURGLARY-TEST CASE 2'
12 REM THE DIM STATEMENTS PRESCRIBE THE SIZE OF THE VARIOUS
13 REM MATRICES USED IN THE PROGRAM.  C IS THE COST MATRIX, P IS THE
14 REM TRANSITION MATRIX OF THE CRIME CATEGORY CONSIDERED, AND X
15 REM CONTAINS THE PREDICTED PRISON POPULATION AT END OF YEAR I.
16 REM DIMENSIONS OF X AND Y CHANGE IF THE NUMBER OF YEARS CONSID-
17 REM ERED CHANGES.  ALL OTHER MATRICES CHANGE ONLY IF THE
18 REM NUMBER OF MARKOV STATES IS CHANGED.
20 DIM B(1,1)
21 DIM C(4,4)
22 DIM D(4,4)
23 DIM P(4,4)
24 DIM Q(4,4)
25 DIM R(4,4)
26 DIM S(4,4)
27 DIM T(4,1)
28 DIM U(4,1)
29 DIM V(4,4)
30 DIM W(1,4)
31 DIM X(20,1)
32 DIM Y(20,1)
33 DIM K(4,4)
34 DIM A(1,4)
35 DIM F(1,4)
36 DIM M(1,4)
46 REM LINES 50 THRU 53 REPRESENT ROWS 1 THRU 4 OF THE TRANSITION MATRIX
```

```
42 MAT READ P
43 MAT READ C
44 MAT READ M
45 MAT F=ZER
50 DATA .502,.242,0,.256
51 DATA .062,.325,.093,.520
52 DATA 0,.116,.626,.258
53 DATA .12,0,0,.88
55 REM LINES 60 THRU 63 REPRESENT ROWS 1THRU 4 OF THE COST MATRIX.
60 DATA 4490.8,2606.12,0,2020.4
61 DATA 6976.12,621.44,2656.12,60.72
62 DATA 0,2606.12,4490.8,2020.4
63 DATA6397.4,0,0,-550
65 REM LINE 70 REPRESENTS THE POPULATION OF EACH MARKOV STATE (IN(C),
66 REM OUT(P), IN(TV), AND OUT(D) RESPECTIVELY) AT TIME ZERO.
70 DATA 1679,667,250,1700
75 REM IN LINE 80, Z IS THE INTEREST RATE USED TO COMPUTE EQUIVALENT
76 REM ANNUAL COST.
80 Z=.10
81 E=EXP(Z)-1
82 L=0
90 MAT O=P
91 MAT R=P
92 MAT D=TRN(C)
93 MAT K=P*D
94 FOR G=1 TO 4
95 U(G,1)=K(G,G)
96 NEXT G
97 PRINT
98 PRINT
100 REM THE COLUMNS OF THE PRINTOUT ARE THE PROPORTIONS OF THE CURRENT
101 REM CONVICTED POPULATION THAT WILL BE IN EACH STATE AFTER YEAR I.
103 REM IN(C) IS IN BY CONVICTION, OUT(P)IS ON PAROLE, IN(TV) IS IN
104 REM BY TECH VIOL, AND OUT(D) IS FREE.
110 PRINT'YEAR','IN(C)','OUT(P)','IN(TV)','OUT(D)'
111 PRINT
```

```
112 REM ENTER A CHANGE IN TIME PERIOD IN 120,OR A CHANGE IN THE
113 REM NUMBER OF MARKOV STATES IN 125.
120 FOR I=1 TO 20
125 FOR H=1 TO 4
130 V(1,H)=R(1,H)
135 NEXT H
140 MAT B=V*U
141 Y(I,1)=B(1,1)
142 L=L+(Y(I,1)*EXP((-Z)*I))
143 PRINT I,R(1,1),R(1,2),R(1,3),R(1,4)
170 MAT R=Q*P
171 MAT Q=R
172 NEXT I
179 PRINT
180 PRINT'THE TRANSITION MATRIX AFTER 20 YEARS IS'
181 MAT PRINT R
182 PRINT
185 REM LINE 190 COMPUTES EQUIVALENT ANNUAL COST
190 A=L*(E/(1-EXP((-Z)*I)))
191 PRINT'EQUIVALENT ANNUAL COST PER CAREER IS',A
195 REM LINES 200 THRU 210 COMPUTE AND PRINT THE EXPECTED NUMBER OF
196 REM RETURNS BY CONVICTION
200 MAT Q=P
201 FOR J=1 TO 4
202 T(J,1)=-P(J,1)
203 Q(J,J)=Q(J,J)-1
204 Q(J,4)=-1
205 NEXT J
206 MAT S=INV(Q)
207 MAT V=S*T
208 PRINT
209 PRINT'EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS',V(4,1)*[illegible]
210 PRINT
215 P1=46.55
216 Q1=15.7
219 PRINT
```

```
220 PRINT' ',' ',' ','PRISON'
221 PRINT' ','YEAR',' ','POPULATION'
222 FOR I=1 TO 10
223 F(1,1)=P1*O1
224 MAT N=M*R
225 N(1,1)=N(1,1)+F(1,1)
226 MAT M=N
227 P1=P1+.75
228 O1=O1-.67
233 X(I,1)=M(1,1)+M(1,3)
234 PRINT' ',I,' ',X(I,1)
235 NEXT I
300 END
```

OUTPUT FOR CRIME CATEGORY OF
ASSAULT

| YEAR | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| 1 | .514 | .288 | 0 | .198 |
| 2 | .314416 | .219456 | .035424 | .430704 |
| 3 | .236255 | .149476 | .04931 | .564959 |
| 4 | .207585 | .111374 | .049451 | .63159 |
| 5 | .198272 | .093686 | .044853 | .663189 |
| 6 | .19609 | .086033 | .039781 | .678097 |
| 7 | .196256 | .082862 | .035644 | .685238 |
| 8 | .197 | .081598 | .032648 | .688754 |
| 9 | .197732 | .081118 | .030605 | .690545 |
| 10 | .1983 | .080951 | .029258 | .69149 |
| 11 | .198701 | .080902 | .02839 | .692007 |
| 12 | .19897 | .080895 | .027837 | .692298 |
| 13 | .199145 | .080901 | .027487 | .692467 |
| 14 | .199258 | .080908 | .027268 | .692566 |
| 15 | .199329 | .080914 | .02713 | .692626 |
| 16 | .199374 | .080919 | .027045 | .692662 |
| 17 | .199403 | .080922 | .026991 | .692684 |
| 18 | .19942 | .080925 | .026958 | .692697 |
| 19 | .199431 | .080926 | .026937 | .692705 |
| 20 | .199438 | .080927 | .026924 | .692711 |

THE TRANSITION MATRIX AFTER 20 YEARS IS

| | | | |
|---|---|---|---|
| .199442 | .080927 | .026916 | .692714 |
| .199444 | .080928 | .026913 | .692715 |
| .199422 | .080925 | .026954 | .692699 |
| .199453 | .080929 | .026896 | .692722 |

EQUIVALENT ANNUAL COST PER CAREER IS 913.478

EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS 3.98899

## OUTPUT FOR CRIME CATEGORY OF LARCENY

| YEAR | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| 1 | .59 | .198 | 0 | .212 |
| 2 | .392712 | .187308 | .015444 | .404536 |
| 3 | .30654 | .145921 | .024726 | .522812 |
| 4 | .272389 | .115017 | .027577 | .585017 |
| 5 | .260523 | .097526 | .027034 | .614916 |
| 6 | .257362 | .088898 | .025315 | .628426 |
| 7 | .257192 | .085036 | .023515 | .634257 |
| 8 | .257816 | .083454 | .022035 | .636694 |
| 9 | .258489 | .082873 | .020942 | .637696 |
| 10 | .259015 | .082694 | .020181 | .638109 |
| 11 | .259382 | .082661 | .019669 | .638288 |
| 12 | .259625 | .082673 | .019331 | .638371 |
| 13 | .259782 | .082693 | .01911 | .638414 |
| 14 | .259883 | .08271 | .018967 | .638439 |
| 15 | .259948 | .082723 | .018875 | .638455 |
| 16 | .259989 | .082731 | .018815 | .638465 |
| 17 | .260015 | .082736 | .018777 | .638471 |
| 18 | .260032 | .08274 | .018752 | .638475 |
| 19 | .260043 | .082742 | .018737 | .638478 |
| 20 | .26005 | .082743 | .018726 | .63848 |

THE TRANSITION MATRIX AFTER 20 YEARS IS

| | | | |
|---|---|---|---|
| .260054 | .082744 | .01872 | .638481 |
| .260053 | .082744 | .018722 | .638481 |
| .25999 | .082732 | .018815 | .638464 |
| .260069 | .082747 | .018698 | .638485 |

EQUIVALENT ANNUAL COST PER CAREER IS 1110.72

EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS 5.20125

OUTPUT FOR CRIME CATEGORY OF
BURGLARY

| YEAR | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| 1 | .502 | .242 | 0 | .256 |
| 2 | .323328 | .200134 | .022506 | .454032 |
| 3 | .274606 | .1459 | .032701 | .546793 |
| 4 | .267192 | .117665 | .03404 | .581102 |
| 5 | .269268 | .10685 | .032252 | .591629 |
| 6 | .271956 | .103631 | .030127 | .594287 |
| 7 | .27369 | .102988 | .028497 | .594825 |
| 8 | .274639 | .10301 | .027417 | .594934 |
| 9 | .275141 | .103121 | .026743 | .594995 |
| 10 | .275413 | .103201 | .026331 | .595055 |
| 11 | .275568 | .103245 | .026081 | .595106 |
| 12 | .27566 | .103267 | .025929 | .595144 |
| 13 | .275715 | .103279 | .025835 | .59517 |
| 14 | .27575 | .103286 | .025778 | .595186 |
| 15 | .275771 | .10329 | .025742 | .595197 |
| 16 | .275784 | .103292 | .025721 | .595203 |
| 17 | .275792 | .103293 | .025707 | .595207 |
| 18 | .275797 | .103294 | .025699 | .595209 |
| 19 | .275801 | .103295 | .025694 | .595211 |
| 20 | .275802 | .103295 | .025691 | .595211 |

THE TRANSITION MATRIX AFTER 20 YEARS IS

| | | | |
|---|---|---|---|
| .275804 | .103295 | .025689 | .595212 |
| .275802 | .103295 | .025692 | .595211 |
| .275782 | .103291 | .025725 | .595202 |
| .275808 | .103296 | .025682 | .595214 |

EQUIVALENT ANNUAL COST PER CAREER IS 1278.50

EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS 5.51611

OUTPUT FOR CRIME CATEGORY OF
ROBBERY

| YEAR | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| 1 | .609 | .192 | 0 | .199 |
| 2 | .400119 | .175488 | .016704 | .407689 |
| 3 | .290718 | .13195 | .026777 | .550555 |
| 4 | .234382 | .098633 | .029929 | .637056 |
| 5 | .205893 | .077958 | .029202 | .686947 |
| 6 | .191814 | .066112 | .026902 | .715172 |
| 7 | .185081 | .059575 | .024288 | .731057 |
| 8 | .182024 | .056037 | .021917 | .740021 |
| 9 | .180761 | .054144 | .019976 | .745119 |
| 10 | .180339 | .053138 | .018474 | .74805 |
| 11 | .180286 | .052606 | .017352 | .749757 |
| 12 | .180376 | .052325 | .016532 | .750767 |
| 13 | .180505 | .052178 | .015943 | .751373 |
| 14 | .18063 | .052102 | .015524 | .751744 |
| 15 | .180734 | .052062 | .015229 | .751974 |
| 16 | .180817 | .052042 | .015022 | .752119 |
| 17 | .180879 | .052032 | .014878 | .752212 |
| 18 | .180924 | .052027 | .014778 | .752272 |
| 19 | .180957 | .052024 | .014708 | .752311 |
| 20 | .18098 | .052023 | .01466 | .752337 |

THE TRANSITION MATRIX AFTER 20 YEARS IS

| | | | |
|---|---|---|---|
| .180996 | .052023 | .014627 | .752354 |
| .181001 | .052021 | .014615 | .752362 |
| .180817 | .052017 | .014964 | .752202 |
| .18105 | .052023 | .014523 | .752404 |

EQUIVALENT ANNUAL COST PER CAREER IS 755.504

EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS 3.62069

# APPENDIX IV

## TEST CASE RESULTS

OUTPUT FOR CRIME CATEGORY OF
BURGLARY-TEST CASE 1

| YEAR | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| 1 | .502 | .242 | 0 | .256 |
| 2 | .310528 | .200134 | .022506 | .466832 |
| 3 | .247655 | .142802 | .032701 | .576842 |
| 4 | .23124 | .110136 | .033752 | .624872 |
| 5 | .229139 | .09567 | .031371 | .64382 |
| 6 | .230409 | .090183 | .028536 | .650872 |
| 7 | .231905 | .088379 | .02625 | .653466 |
| 8 | .232985 | .087889 | .024652 | .654474 |
| 9 | .233668 | .087806 | .023606 | .65492 |
| 10 | .234082 | .087823 | .022943 | .655152 |
| 11 | .23433 | .087852 | .02253 | .655288 |
| 12 | .234479 | .087873 | .022274 | .655373 |
| 13 | .23457 | .087887 | .022116 | .655427 |
| 14 | .234626 | .087895 | .022018 | .655462 |
| 15 | .23466 | .087899 | .021957 | .655483 |
| 16 | .234681 | .087902 | .02192 | .655497 |
| 17 | .234694 | .087904 | .021897 | .655505 |
| 18 | .234702 | .087905 | .021882 | .65551 |
| 19 | .234707 | .087905 | .021874 | .655513 |
| 20 | .234711 | .087906 | .021868 | .655515 |

THE TRANSITION MATRIX AFTER 20 YEARS IS

| | | | |
|---|---|---|---|
| .234712 | .087906 | .021865 | .655517 |
| .234711 | .087906 | .021867 | .655516 |
| .23469 | .087903 | .021904 | .655502 |
| .234718 | .087907 | .021855 | .65552 |

EQUIVALENT ANNUAL COST PER CAREER IS 1347.12

EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS 4.69431

OUTPUT FOR CRIME CATEGORY OF
BURGLARY-TEST CASE 2

| YEAR | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| 1 | .502 | .242 | 0 | .256 |
| 2 | .297728 | .200134 | .022506 | .479632 |
| 3 | .219424 | .139704 | .032701 | .608171 |
| 4 | .191793 | .102298 | .033463 | .672446 |
| 5 | .183316 | .083542 | .030462 | .70268 |
| 6 | .181526 | .075047 | .026839 | .716588 |
| 7 | .181769 | .071433 | .02378 | .723017 |
| 8 | .182439 | .069962 | .02153 | .726069 |
| 9 | .18305 | .069386 | .019984 | .72758 |
| 10 | .183503 | .069167 | .018963 | .728368 |
| 11 | .183811 | .069087 | .018303 | .728799 |
| 12 | .184012 | .069059 | .017883 | .729046 |
| 13 | .184141 | .069049 | .017617 | .729192 |
| 14 | .184223 | .069047 | .01745 | .72928 |
| 15 | .184274 | .069046 | .017345 | .729334 |
| 16 | .184307 | .069047 | .017279 | .729367 |
| 17 | .184327 | .069047 | .017238 | .729388 |
| 18 | .18434 | .069047 | .017212 | .729401 |
| 19 | .184347 | .069047 | .017196 | .729409 |
| 20 | .184352 | .069047 | .017186 | .729414 |

THE TRANSITION MATRIX AFTER 20 YEARS IS

| | | | |
|---|---|---|---|
| .184356 | .069047 | .01718 | .729417 |
| .184355 | .069047 | .01718 | .729417 |
| .184334 | .069047 | .017224 | .729395 |
| .184363 | .069047 | .017165 | .729425 |

EQUIVALENT ANNUAL COST PER CAREER IS 1153.71

EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS 3.68721

OUTPUT FOR CRIME CATEGORY OF
BURGLARY-INC IN PAROLE RATE
(TEST CASE 3)

| YEAR | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| 1 | .477 | .292 | 0 | .231 |
| 2 | .296453 | .234184 | .027156 | .442207 |
| 3 | .253213 | .165824 | .038779 | .542184 |
| 4 | .250344 | .132329 | .039697 | .577629 |
| 5 | .254697 | .120712 | .037157 | .587433 |
| 6 | .25821 | .117913 | .034487 | .58939 |
| 7 | .260143 | .11772 | .032555 | .589583 |
| 8 | .261095 | .117997 | .031327 | .589581 |
| 9 | .261566 | .118223 | .030584 | .589627 |
| 10 | .261815 | .118347 | .030141 | .589697 |
| 11 | .261957 | .118409 | .029874 | .58976 |
| 12 | .262042 | .11844 | .029713 | .589805 |
| 13 | .262094 | .118456 | .029615 | .589834 |
| 14 | .262127 | .118465 | .029556 | .589852 |
| 15 | .262147 | .118471 | .029519 | .589863 |
| 16 | .262159 | .118474 | .029497 | .58987 |
| 17 | .262167 | .118476 | .029483 | .589874 |
| 18 | .262171 | .118477 | .029475 | .589876 |
| 19 | .262174 | .118478 | .02947 | .589878 |
| 20 | .262176 | .118479 | .029466 | .589879 |

THE TRANSITION MATRIX AFTER 20 YEARS IS

| | | | |
|---|---|---|---|
| .262177 | .118479 | .029464 | .589879 |
| .262176 | .118479 | .029466 | .589879 |
| .26216 | .118474 | .029495 | .58987 |
| .262181 | .11848 | .029458 | .589881 |

EQUIVALENT ANNUAL COST PER CAREER IS 1270.2

EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS 5.64095

OUTPUT FOR CRIME CATEGORY OF
BURGLARY--DEC IN PAROLE RATE
(TEST CASE 4)

| YEAR | IN(C) | OUT(P) | IN(TV) | OUT(D) |
|---|---|---|---|---|
| 1 | .527 | .192 | 0 | .281 |
| 2 | .345833 | .163584 | .017856 | .472727 |
| 3 | .286942 | .120743 | .026838 | .565478 |
| 4 | .2718 | .096106 | .0287 | .603394 |
| 5 | .269876 | .085314 | .027622 | .617188 |
| 6 | .270952 | .081366 | .025916 | .621766 |
| 7 | .272189 | .080177 | .024438 | .623195 |
| 8 | .273054 | .079931 | .023366 | .623649 |
| 9 | .273585 | .079946 | .022645 | .623824 |
| 10 | .273901 | .080005 | .022177 | .623917 |
| 11 | .274089 | .080054 | .021878 | .623979 |
| 12 | .274204 | .080087 | .021687 | .624022 |
| 13 | .274275 | .080107 | .021567 | .624051 |
| 14 | .27432 | .080119 | .02149 | .624071 |
| 15 | .274348 | .080126 | .021441 | .624084 |
| 16 | .274366 | .080131 | .02141 | .624093 |
| 17 | .274378 | .080134 | .02139 | .624098 |
| 18 | .274385 | 080136 | .021377 | .624102 |
| 19 | .27439 | .080137 | .021369 | .624104 |
| 20 | .274393 | .080138 | .021364 | .624105 |

THE TRANSITION MATRIX AFTER 20 YEARS IS

| | | | |
|---|---|---|---|
| .274395 | .080138 | .021361 | .624106 |
| .27439 | .080137 | .021369 | .624104 |
| .27435 | .080127 | .021437 | .624085 |
| .274402 | .08014 | .021348 | .62411 |

EQUIVALENT ANNUAL COST PER CAREER IS 1303.89

EXPECTED NO. OF RETURNS TO PRISON BY CONVICTION IS 5.09187

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